ALLIS-CHALMERS

ELECTRICAL REVIEW

December • 1943

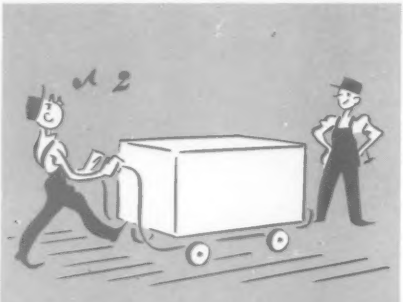
Women in industry — they're not only on the production lines and in the offices — they're in the laboratories . . . engaged in the research that is shaping the post-war world today.

FIGHT FRICTION!

It's Electric Motor Enemy No. 4...

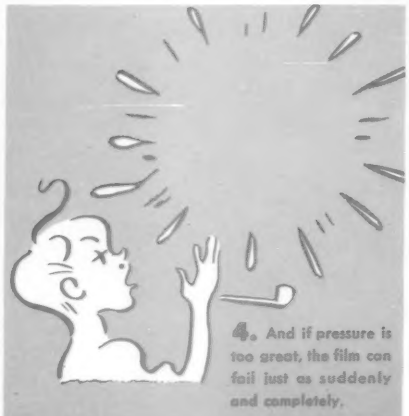
in Allis-Chalmers' new "Guide to Wartime Care of Electric Motors".

1. Like a motor without oil. Simple! Yet every day hundreds of workers overlook the importance of adequate motor lubrication.

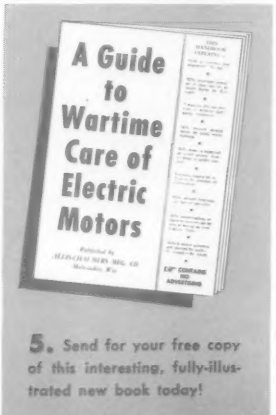


2. Like a motor with oil. Pictures like these make motor maintenance easy to put across in training new employees.

3. Oil film protecting bearings often is no thicker than the wall of a soap bubble.



4. And if pressure is too great, the film can fail just as suddenly and completely.



5. Send for your free copy of this interesting, fully-illustrated new book today!

ONE OF A MOTOR'S most dangerous enemies is friction. In peacetime, instructions for guarding against it were based on 8-hour-day, 6-day-week operation. Today, with motors working up to *3 and 4 times* as many hours a week, those instructions are dangerously obsolete!

To help put U. S. motor maintenance on an efficient wartime footing, Allis-Chalmers has published "Guide to Wartime Care of Electric Motors". This valuable book explains the *9 main enemies* of electric motors . . . tells you how to fight them. Its recommendations are simple and practical . . . ideal for training new men or as a review for experienced men. Book is fully illustrated with stimulating, understandable sketches like those shown above—*contains no advertising*. Over 100,000 copies in use by industry and armed forces. Send for your *free* copy today! ALLIS-CHALMERS MFG. CO., MILWAUKEE 1, WIS.

A 1658

ALLIS-CHALMERS MOTORS

When you do need new motors, look into the strength, solidity and all-around protection of the new "Safety Circle"—protected top, sides, ends and bottom.

WE WORK FOR VICTORY — WE PLAN FOR PEACE

Vol. VIII . . . No. 4

December, 1943

Allis-Chalmers
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ALLIS-CHALMERS

ELECTRICAL REVIEW

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TRANSFORMERS FOR SHIPS

When action comes, electrical equipment plays a vital role on shipboard. That's why marine transformers are built better than ever now . . . to resist shock, fire, and vibration!

R. W. Beard and E. M. Leonard

TRANSFORMER DIVISION • ALLIS-CHALMERS MANUFACTURING COMPANY

● The modern cargo, passenger, or fighting ship uses electricity for nearly every auxiliary. Lamps, motors, and heating units need power for lighting, ventilating, pumping, cooking, laundering, steering, storing and preparing food, loading cargo, operating radio, and internal communications, and for many other applications. Is it any wonder, then, that a modern ship is a floating electric power plant?

The distribution of all this electrical energy requires a system not unlike that of a large industrial plant. There are, however, problems involved on board ship which are not encountered in plants or distribution systems ashore.

Reducing weight

Dead-weight is a first consideration in marine equipment design, because excess weight reduces the speed, cargo-carrying capacity, and maneuverability of a ship. Some vessels require d-c auxiliary power, because they have many variable speed motors and winches requiring a high starting torque; others have few winches and many constant speed applications — for these, alternating current promotes lower overall weight, higher efficiency, better voltage regulation, and less maintenance (Fig. 1).

Distribution is generally at 440 volts, three-phase, with transformer banks located near the load to supply 120 or 230 volt equipment. This makes possible a saving in weight of copper cables and improves the voltage condition at the load. With distribution at the higher voltage, there is less line loss and voltage drop; and locating step-down transformers at the utilization points provides for safety and flexibility of appliances.

Some liquid-filled transformers have been used on board ship, but practically all modern vessels with a-c auxiliaries have dry type transformers with ship's cables terminating inside a steel case, to make a simple and fool-proof installation. Ship's cables can be run straight through a three-phase bank of single-phase units, anchored to the transformers (Fig. 2), and "T" connectors can tap the transformer leads to the cables. Single-phase units are usually preferred over three-phase transformers, because they are easier to handle, and even if one unit is damaged the open delta bank can still be kept temporarily in service (Fig. 3).

High temperature

High ambient temperature conditions are often found in locations on board ship where transformers must be installed. Ambient temperatures of 50 C are not uncommon and, below decks, the ventilation may not be ideal, so the units are designed liberally with respect to temperature rise. With Class "A" insulation in commercial installations a maximum temperature rise of 55 C above a 40 C ambient is standard practice; but with shipboard ambients of 50 C, a special design having a maximum rise of 45 C at full load is used. Likewise, for Class "B" insulations, a temperature rise of 70 C is used instead of standard 80 C rise.

Fire hazard on ships exposed to naval action has led to a quick changeover from Class "A" to Class "B"

Fig. 1 — When auxiliaries are constant speed, as on this PF escort vessel, considerable weight can be saved by using a-c electrical equipment instead of d-c. OFFICIAL U. S. NAVY PHOTO

AT LEFT: Anode assembly for an excitron rectifier is lowered into the excitron tank. The steel anode shaft, with carbon anode head at the lower end and a fin-type radiator at the upper end, is insulated from the anode plate by means of a ceramic bushing. Mercury seals are used to make vacuum-tight joints between the anode insulator, plate, and shaft.

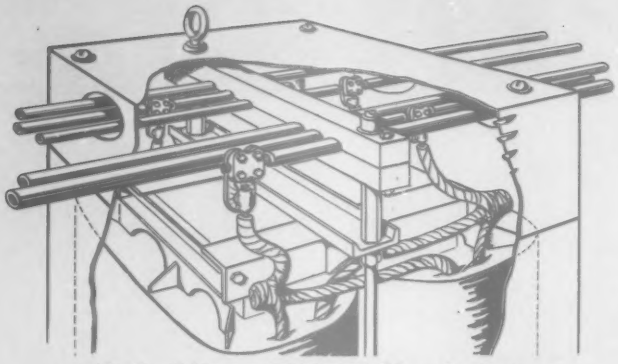


Fig. 2 — Cables run right through this marine transformer, and "T" connecters tap off to the winding.

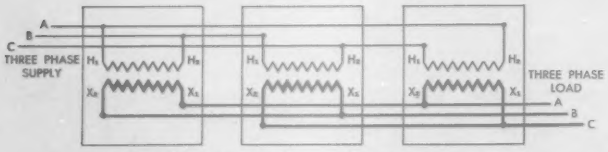


Fig. 3 — Three single-phase marine transformers connected in a closed delta to insure continuity of service.

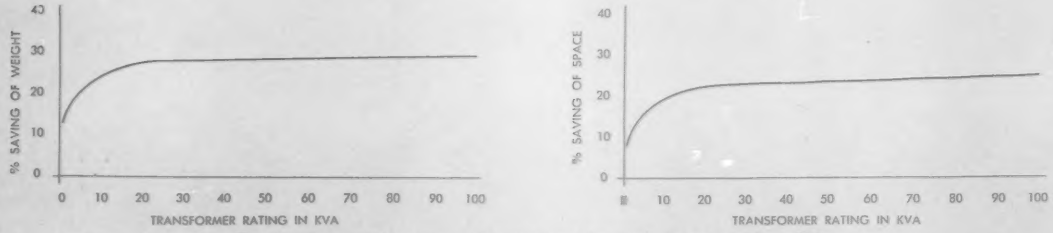


Fig. 4 — Savings in space and weight can be made by using Class "B" insulation instead of Class "A" in marine dry type transformers.

Fig. 5 — Marine dry type transformer of less than 10 kva capacity for bulkhead mounting.

Fig. 6 — Deck mounting dry type marine transformer, rated 15 kva.

Fig. 7 — Auto transformer type balance coil for bringing out the neutral of a three-wire d-c marine generator.

insulation. Class "B" insulation, like mica, glass covering for wire, glass tapes and tubing, asbestos, and similar inorganic materials, will not support combustion. These materials can be worked at temperatures 20 to 25 degrees higher than organic materials without sacrificing their useful life. Experience may indicate that properly designed Class "B" insulated transformers can be operated at even higher temperatures without shortening life expectancy. Furthermore, Class "B" insulated transformers weigh 20 to 25 percent less (Fig. 4) and also release vital space for cargo and living quarters. Most important, though, is the removal of a possible fire hazard, present with any equipment containing organic insulating materials.

Shipboard transformers range from 750 volt-amperes to 200 kva and larger. Units of 10 kva and smaller are usually mounted on bulkheads (Fig. 5) or switchboards, and units 15 kva and larger are deck mounted (Fig. 6).

Balance coils

A special form of dry type transformer used extensively on shipboard is the d-c generator balance coil or auto transformer (Fig. 7). Auxiliary generators for lighting service have collector rings which deliver alternating current to the balance coil at a frequency which depends upon the number of poles and the speed of the generator. The midpoint of the balance coil provides a neutral for 3-wire, 120/240 volt d-c lighting circuits (Fig. 8).

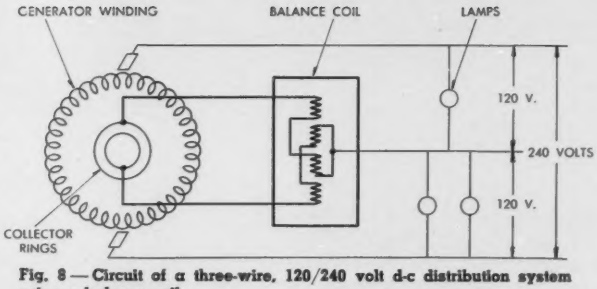


Fig. 8 — Circuit of a three-wire, 120/240 volt d-c distribution system using a balance coil.

Vibration and shock

Shipboard transformers are similar electrically to commercial dry type transformers which are used ashore, but mechanically they are designed for special conditions such as extreme vibration and shock. This requires rigid mounting structures, welded bracing, and the elimination of all cast iron and certain other materials that might be ruptured or deformed under shock. This consideration, along with the urgent requirements for smaller and lighter units, has resulted in a marine transformer that is quite different in appearance and construction from its industrial contemporaries.

Fig. 9 — Alternating current auxiliaries are used in this "frigate" type convoying warship, shown here being launched. Dry type transformers step the voltage down to the proper value for auxiliaries.

OFFICIAL U. S. NAVY PHOTO

A FIVE-WINDING TRANSFORMER EQUIVALENT CIRCUIT

A five-winding transformer seems complicated, but terminal characteristics can be found with simple equations. And interesting things happen . . . even resistance appears negative!

L. C. Aicher

TRANSFORMER DIVISION • ALLIS-CHALMERS MANUFACTURING COMPANY

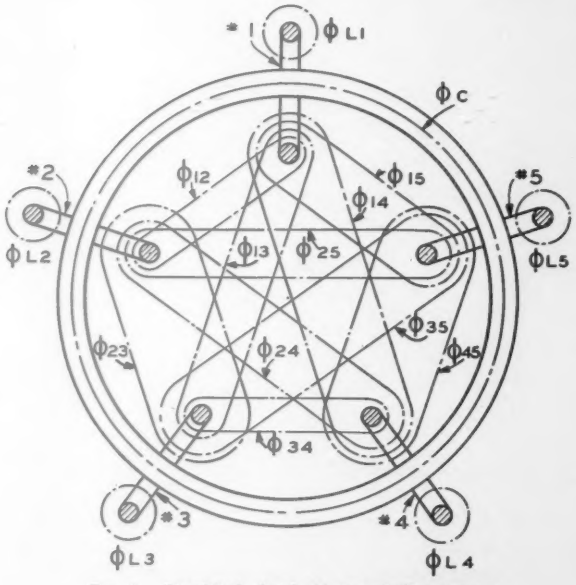


Fig. 1 — Simplified sketch of five-winding transformer showing mutual and leakage flux linkages.

● The advent of interconnected transmission circuits has encouraged the design and application of multicircuit transformers. The most common of these is the three-winding transformer, followed by the four-winding transformer. Recently a practical equivalent circuit for a five-winding transformer was introduced.[1]

1 "A Useful Equivalent Circuit for a Five-Winding Transformer" by L. C. Aicher, AIEE Technical Paper 43-2, Electrical Engineering, Vol. 62, No. 2, February, 1943, Pages 66-70.

AT LEFT: Designed for 275 percent peak loads, these 4,000 hp motors are being tested for the rigorous operation which will be required of them when they eventually drive reversing steel-rolling mills. The motor in the foreground is rated 0/80/160; the other 0/50/120.

Five-winding uses

At first thought one is apt to wonder what use there could be for a five-winding transformer. A few possibilities are:

(1) When five circuits are interconnected.

(2) Where it is desired to feed several distribution systems from one or more transmission circuits, resulting in a total of five circuits.

(3) Where auxiliary loads, such as synchronous condensers, or local loads have voltages different from the transmission circuit or generator voltages.

(4) Where a generating system feeds several outgoing transmission circuits of different voltages.

(5) Split winding generators necessitate multicircuit transformers, with the interesting feature that they require two separate primary windings of the same voltage.

(6) Occasionally it is desirable to subdivide the secondary load into separate secondary windings to reduce the short circuit kva by the manipulation of transformer reactances, without serious derangement of the system voltage regulation.

(7) Load ratio control transformers, for voltage control, phase angle control, or both simultaneously.

(8) Specialty transformers, such as for rectifiers, where there are several secondary windings of identical kva and voltage for multiphase connections. An example is a transformer for a twelve-phase power rectifier.

Multicircuit transformers present many problems that cannot be solved by two-winding methods. These complications are related to the leakage-impedance phenomena associated with the many fluxes (Fig. 1). The more important characteristics affected by these phenomena are:

(a) Voltage regulation
(b) Load division between circuits
(c) Parallel operation with other transformers
(d) Efficiency
(e) Short-circuit characteristics.

The various leakage fluxes caused by load currents interlink the different circuits and affect the various voltages in complicated and sometimes unexpected ways.

Impedances of windings

The theory of a five-winding transformer is no different than that of one with a lesser number of windings. Such a transformer consists of five separate windings that are mutually coupled by a single magnetic core, which can be conveniently illustrated as in Fig. 1.

The five windings can be designated as in Fig. 3 with the numbers 1, 2, 3, 4, and 5. Then the ten impedances which can be measured at the terminals of the transformer are:

$$\begin{matrix} Z_{12} & Z_{13} & Z_{14} & Z_{15} \\ & Z_{23} & Z_{24} & Z_{25} \\ & & Z_{34} & Z_{35} \\ & & & Z_{45} \end{matrix}$$

Each of these impedances is measured, by applying sufficient voltage to one of the windings whose number appears in the subscript, to circulate a current in a short circuit on the other winding, whose number appears in the subscript, the magnitude of current adjusted to the kva base chosen. All other windings remain open-circuited.

A true equivalent circuit for a transformer is one which cannot be distinguished from the actual transformer by any observations at its terminals. The terminal characteristics of a transformer are of interest rather than the characteristics of some particular coil within the transformer.

As in most practical transformer equivalent circuits, magnetizing current has been neglected. The result is an equivalent circuit (Fig. 4) accurate enough for most power circuit problems. The circuit contains components which represent winding resistance, self-inductance, and load or mutual impedance.

Evaluation of circuit

The various network parameters of Fig. 3 can be evaluated from test data or design data with these equations:

$$Z_1 = \frac{N}{2} - \frac{1}{Z_t}(Z_6 Z_{10}) \quad \ldots\ldots (1)$$

$$Z_2 = \frac{K}{2} - \frac{1}{Z_t}(Z_6 Z_7) \quad \ldots\ldots (2)$$

$$Z_3 = \frac{O}{2} - \frac{1}{Z_t}(Z_7 Z_8) \quad \ldots\ldots (3)$$

$$Z_4 = \frac{R}{2} - \frac{1}{Z_t}(Z_8 Z_9) \quad \ldots\ldots (4)$$

$$Z_5 = \frac{T}{2} - \frac{1}{Z_t}(Z_9 Z_{10}) \quad \ldots\ldots (5)$$

$$Z_6 = \frac{U}{2PS} \quad \ldots\ldots (6)$$

$$Z_7 = \frac{U}{2SM} \quad \ldots\ldots (7)$$

$$Z_8 = \frac{U}{2MQ} \quad \ldots\ldots (8)$$

$$Z_9 = \frac{U}{2QL} \quad \ldots\ldots (9)$$

$$Z_{10} = \frac{U}{2LP} \quad \ldots\ldots (10)$$

in which

$$K = Z_{23} + Z_{12} - Z_{13} \quad \ldots\ldots (11)$$

$$L = Z_{13} + Z_{24} - Z_{14} - Z_{23} \quad \ldots\ldots (12)$$

$$M = Z_{14} + Z_{25} - Z_{15} - Z_{24} \quad \ldots\ldots (13)$$

$$N = Z_{12} + Z_{15} - Z_{25} \quad \ldots\ldots (14)$$

$$O = Z_{34} + Z_{23} - Z_{24} \quad \ldots\ldots (15)$$

$$P = Z_{24} + Z_{35} - Z_{34} - Z_{25} \quad \ldots\ldots (16)$$

$$Q = Z_{13} + Z_{25} - Z_{12} - Z_{35} \quad \ldots\ldots (17)$$

$$R = Z_{45} + Z_{34} - Z_{35} \quad \ldots\ldots (18)$$

$$S = Z_{14} + Z_{35} - Z_{13} - Z_{45} \quad \ldots\ldots (19)$$

$$T = Z_{45} + Z_{15} - Z_{14} \quad \ldots\ldots (20)$$

$$U = MQL + QLP + LPS + PSM + SMQ \quad \ldots\ldots (21)$$

and

$$Z_t = Z_6 + Z_7 + Z_8 + Z_9 + Z_{10} \quad \ldots\ldots (22)$$

Negative impedance

Negative resistance or reactances are of no practical value as negative impedances by themselves, and they can be considered as mathematical fictions. They reproduce faithfully the *terminal* characteristics of the transformer, but they cannot necessarily be applied to internal coils.

Negative resistance may appear in high-efficiency transformers in which stray impedance losses become appreciable when compared with the low ohmic copper losses.

The total leakage reactance between a pair of windings cannot be negative, but there is no reason why the mutual effect between circuits for load currents may not be negative, depending on how the leakage field of one interacts with that of the other. In the circuits considered, the individual leakage impedances assigned to a circuit constitute mutual load impedance for the other circuits, and as such may be either positive or negative.

Fig. 2—Each of these 4,280 kva rectifier transformers has one primary and four separate secondary windings for each phase.

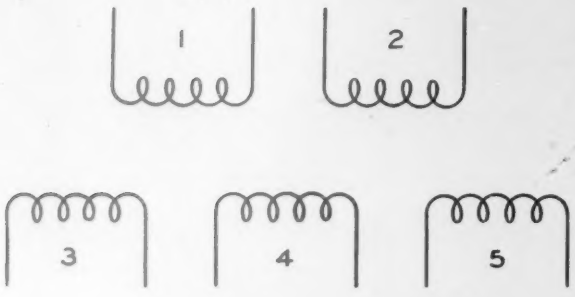


Fig. 3 — Terminal connections of a five-winding transformer.

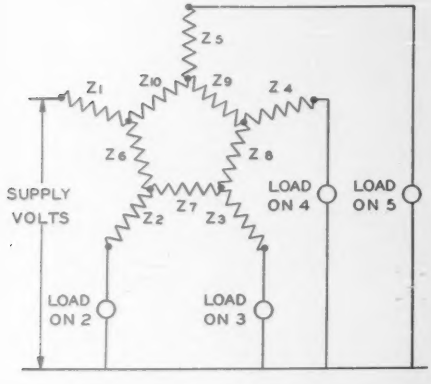


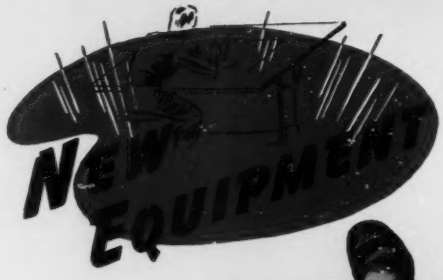
Fig. 4 — Equivalent circuit of a five-winding transformer, with magnetizing current neglected.

The total copper losses, including stray impedance losses, are correctly represented by the equivalent circuit, whatever the signs of its branches may be; but the simple equivalent circuit provides no means of distributing the losses within the transformer windings. However, the total impedance losses causing the heating of the oil are given by the equivalent circuit.

This method may be used when only the reactance component of impedance is important, or when complex quantities represent the impedance units. Regardless of the degree of simplicity or complexity, the same rules apply. Observance of the sign, positive or negative, accompanying each numerical value is necessary.

Only a single phase solution need be made for any balanced three-phase bank. However, if unlike transformers are involved a solution for each phase must be made.

The voltage at each transformer terminal can be determined by introducing load currents to Fig. 4. Each current is applied to the complete network separately, then the rule of superposition is applied to arrive at the composite effect of all loads on each circuit voltage.



New 400 Ampere a-c Welder For Heavy Industry

A new tool for heavy industry, the Ampac "400" welder, now supplements the 200 ampere alternating current unit introduced recently. The 400-ampere size of the welder was chosen as ideal after an extensive investigation of the average industrial welding shop's wartime needs.

Designed from the ground up as an exceptionally sturdy, self-cooled unit, the new welder will handle ¼ inch electrodes on the basis of the Nema duty cycle, and ample capacity is provided for rods up to ⅜ inch size when needed. The unit is also adaptable for automatic welding. A range of 50 to 500 amperes is covered by the Ampac "400," with power factor correction available if desired. The "400" uses the same basic electric circuit as the versatile Ampac "200" welder.

Outstanding features of the Ampac "400" are low idling loss, high power factor, and extremely high efficiency and excellent welding characteristics over entire range. Temperature rise and voltage breakdown tests better all NEMA requirements. The new welder requires only eight turns of the control handle to cover its entire range.

Ampac Performance at Various Amperage Settings

	No Load	100 Amp.	200 Amp.	300 Amp.	400 Amp.
Power Factor	...	53%	56%	58%	60%
Primary Amperage (220 v)	4.8	38	70	102	133
Primary Kw	0.2	4.5	8.7	13	17.5
Primary Kva	1.06	8.4	15.5	22.4	29.3
Efficiency	...	89%	92%	92%	91%

Porcelain Bushing Cement Made of Non-Critical Materials

A porcelain bushing cement which has been successfully used for many years by Allis-Chalmers service and erection men is now being put on the market under the trade name of Magna-Bond, in response to an unsolicited demand for the product.

Because Magna-Bond is not manufactured from critical materials, it is possible to supply it much more readily than many other bushing cements. Magna-Bond resists deterioration by air, water, and transformer oil, and even corrosive gases have little effect on it. When the cement is coated with enamel as directed, it will give years of satisfactory service.

For further, more detailed information regarding these new products, write the Editors of ELECTRICAL REVIEW.

THE NINETEEN BASIC U. S. INVENTIONS
III. COMMUNICATION*

Simple electrical inventions—the telegraph, telephone, and vacuum tube—required the efforts of college-trained men. The complicated linotype and typewriter were invented by practical, mechanical men.

Miles Henninger
PATENT ATTORNEY • MILWAUKEE, WISCONSIN

* This is the third of four articles describing the 19 most famous American inventions, the background of their inventors, and the financial returns derived from them.

● Rapid long-distance communication is not only a convenience but essential to both American business and social life. The Morse telegraph, the Bell telephone, and the radio based on the De Forest amplifier provide the three most effective means for homogenizing such a large country as the United States, for promoting intercourse with the entire world.

Morse's Telegraph 1840

Samuel F. B. Morse was born in 1791 at Charlestown, Mass. In 1810 he was graduated from Yale, where he studied and taught the sciences, particularly electricity. However, he wanted to become a painter, so he went to London to work under Benjamin West. For 17 years after his return to the United States, Morse painted portraits, gaining the most success in Charleston, S. C. Morse's competence as a painter earned him the presidency (1826 to 1842) of the National Academy of Design, and a professorship in the arts of design at New York University. In 1829 Morse went to Europe to visit art galleries and further study painting.

AT LEFT: Perhaps the most interesting machine among those considered the nineteen basic U. S. inventions is the linotype. Thousands of them in newspaper, typesetting, and printing plants save an infinite amount of time and labor in producing the printed word. Without them, for example, now-common publishing miracles, such as news from world battlefronts hot off the press a few hours after events actually occur, would be impossible.

While Morse was in Europe, the electrical discoveries of the time were just coming to general attention and they were being widely discussed. The systems of rapid communication in Europe at that time included the French semaphore devised by the Chappe brothers, the German electromagnetic telegraph by Steinheil, and the English electroneedle telegraph invented by Wheatstone. The semaphore system required towers and operators in sight of each other, and its capacity never exceeded 100 words per hour. The German system had two permanent magnets with recording pens, acted upon by a coil, and was capable of sending 360 words per hour. The English system employed one or more magnetic needles movable over a dial bearing letters and numbers and operated at about the same speed as the German system.

In discussing the recent electrical discoveries while returning from England, Morse conceived the idea that electricity could be used more directly and more rapidly for sending messages. He was so enthusiastic about his idea that he lived and worked in a single room for five years while completing his first model, besides teaching design at New York University. He had to make his own electromagnets, had to invent a relay to overcome the voltage drop in the line so as not to go beyond "the limit of the magnetic power," and he even had to insulate his own wire!

After finishing the first model, Morse realized he needed help, so in 1837 he formed a partnership with Professor Leonard D. Gayle of New York University for technical advice and with Alfred Vail for financial aid and experimental assistance. By 1838, messages were sent by a dot-dash code, using a printing type sender, at the rate of 600 words per hour.

Morse asked Congress for $30,000 with which to build an experimental line from Baltimore to Washington but he was refused the money. He went to London and to Paris but could not interest any European government in his telegraph. When he returned, he was without money or even resources for food, because his clients for portraits were all gone. For the next four years, Morse unsuccessfully importuned

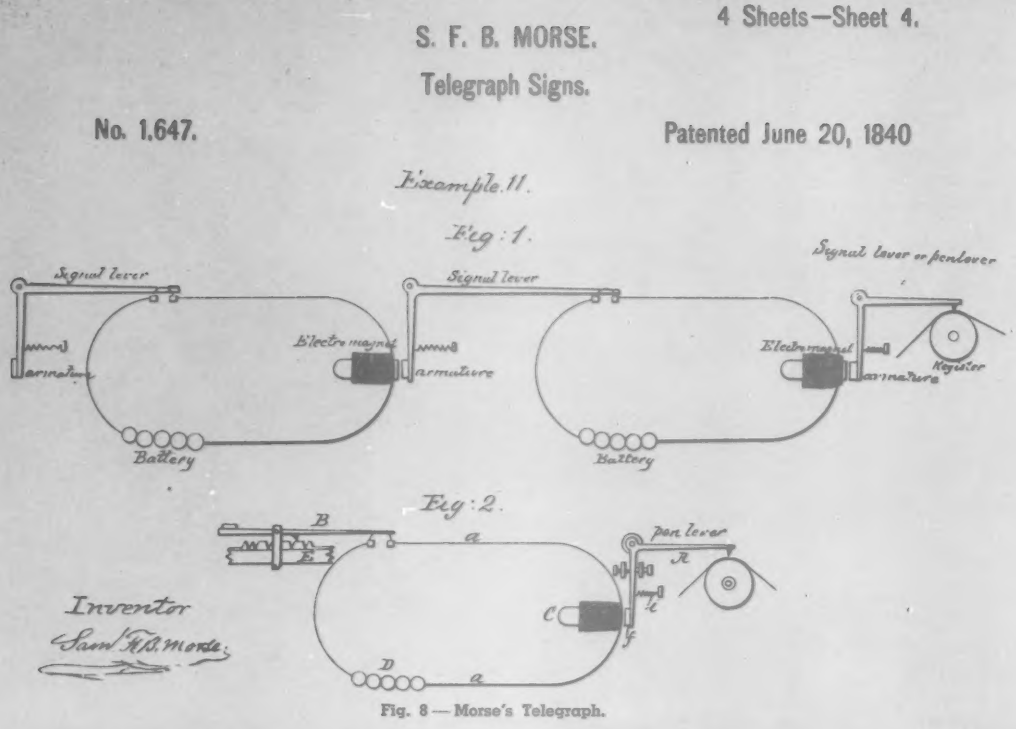


Fig. 8 — Morse's Telegraph.

Congress for funds, but he also improved his batteries as a source of current and developed the sending and receiving key to a point where 20 to 30 words per minute could be sent. He also prosecuted his patent application, which became patent 1,647, issued June 20, 1840 (Fig. 8). It covers both the printing type and the key means for sending and receiving messages.

Congress granted Morse funds in 1843, and he began to build his experimental line, which had a conductor wrapped in cloth soaked in beeswax and tar for insulation. It was placed underground in lead pipe. Twenty thousand dollars was spent for ten miles of line which was a failure when tested. The remaining $10,000 was used to build a line of conductors mounted on door knobs as insulators on the cross arms of short poles. This line, when tested in 1844, proved to be entirely successful.

Morse, however, was refused a British patent because of a description published by Ed. Davy in the London *Mechanics Magazine*, January 20, 1838. And his French patent was forfeited because the telegraph was not put into public use within the French time limit.

Morse next offered his invention to the United States government for $100,000, but the offer was refused. Private capital then took up the telegraph, and many unprofitable small companies were organized. When these were consolidated in 1857 as Western Union, it was said to have been "like collecting all the paupers in the state and arranging them into a union to make rich men of them." But two years after the first telegraph line was built, receipts for the first quarter were only $203.43, although the rate was just one cent for each four characters. By 1853, however, there were 4,500 miles of telegraph lines in the United States, and Morse then had to defend his inventorship against others (14 L. E. 601).

The telegraph replaced the pony express in 1862 and was the basis for the Atlantic cable in 1866. Morse became a wealthy man. He received many decorations, medals, and orders and, in 1858, received a gift of $80,000 from several European nations at the urging of Napoleon III.

Bell's Telephone 1876

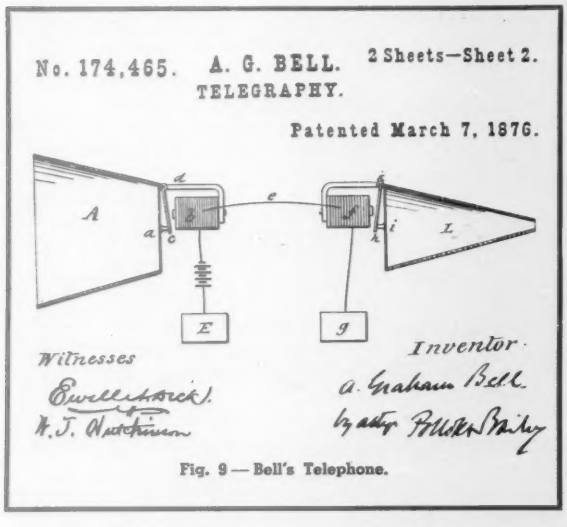
The telephone was invented in the United States and as the result of encouragement given by United States citizens, but its inventor, Alexander Graham Bell, was born (1847) in Edinburgh, Scotland. Bell attended the University of Edinburgh and the University of London, where he was trained in elocution and music, which taught him how sounds are produced. As a boy he made a model of the human head and larynx to study speech. While studying elocution with his father, he came upon Helmholtz's working in transmitting sounds electrically by means of tuning forks set in vibration.[1]

Bell taught at the Boston School for the Deaf, where in 1871 he developed a device which he called the "phono-autograph." It recorded sounds as lines on a smoked glass and was simply a cone with a flexible membrane mounted in the small end, and a lightweight lever moved a pig-bristle point bearing on the

1 3 Journal of the Patent Office Society 433.

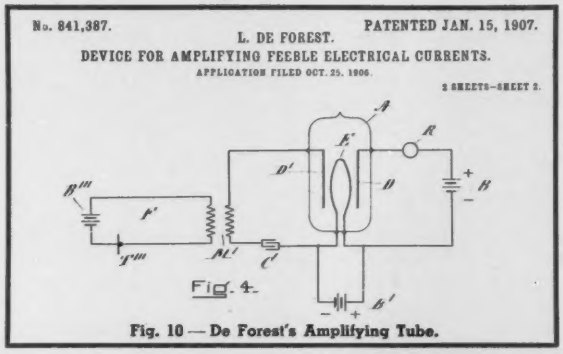
glass. He next tried a human ear for making his tracings. From the action of the ear, Bell conceived the idea that vibrations strong enough to move the chain of ear bones might be used to vary the current flow in an electric circuit, which would reproduce the vibrations at a distance. Bell succeeded in interesting Thomas Sanders and Gardner Hubbard (the fathers of two of his deaf pupils) in his idea, and they financed his experiments for several years, while Professor Joseph Henry encouraged him to do the necessary study and work.

A sound recorder is described by French patent 124,213 to Charles Cros in 1877, and a machine for reproducing sound is shown in French patent 17,898 to Leon Scott in 1857; but the first successful transmission of speech came in 1874 only after many unsuccessful trials of different devices. Patent No. 174,465 was granted March 7, 1876 (Fig. 9) on the device which Bell found successful.


No. 174,465. A. G. BELL. 2 Sheets—Sheet 2.
TELEGRAPHY.
Patented March 7, 1876.
Witnesses
Inventor
Fig. 9 — Bell's Telephone.

The telephone was exhibited at the Centennial Exposition in Philadelphia, but was completely ignored until noticed by Dom Pedro, then Emperor of Brazil, who tested the telephone and exclaimed, "It talks." This brought the telephone to the attention of the exhibit judges and all of the electrical men present. Even so, the telephone came into public use very slowly, and its chief use was burglar and fire alarm connections from stores to police stations and fire houses. The first telephone exchange was established in Boston in 1877 with five banks for customers. By 1896, the ten-party line could be had for $1.50 per month, and telephone service was established.

By August, 1877, a total of 778 telephones were in use, and the demand exceeded manufacturing facilities. But the Bell Telephone association was in financial distress, and the invention was offered to Western Union for $100,000. The offer was refused. Later, Western and others brought forth other claimants to the invention (31 L. E. 863 and 35 F 735) but lost the battle. Bell Telephone stock then rose to $1,000 per share, resulting in the formation of the A. T. & T. Co. in 1885. All original promoters, including Bell, made comfortable fortunes.


No. 841,387. PATENTED JAN. 15, 1907.
L. DE FOREST.
DEVICE FOR AMPLIFYING FEEBLE ELECTRICAL CURRENTS.
APPLICATION FILED OCT. 25, 1906.
2 SHEETS—SHEET 2.
Fig. 4.
Fig. 10 — De Forest's Amplifying Tube.

De Forest's Amplifying Tube 1908

Lee De Forest was born August 26, 1873, at Council Bluffs, Iowa, where his father was a Congregational minister. De Forest was likewise intended to be a minister, but even when a boy he was fascinated by and "inventing" mechanical devices. He grew up in Alabama, where his father was president of Talladega College for Negroes during the reconstruction period following the Civil War. He managed to get through Mount Hermon preparatory school by hard and disagreeable work and entered Yale's Sheffield scientific school on a scholarship established by David De Forest (no relation), the first United States consul to Argentina. While doing post-graduate work in physics on Hertzian waves, he blew out the fuses after repeated warnings, and interrupted an important evening lecture. He was expelled from Sheffield school and finished his post-graduate work at Sloane Laboratory (Yale) in what was little more than advanced physics. The boyhood experiences in Alabama, his unusual appearance, his incessant day dreaming, poverty, and a well developed ego made him determined to acquire wealth and position. This became his driving force.[2]

After receiving his Ph.D. degree, Dr. De Forest went to work in the Western Electric Co. laboratories, where he saw the iron filings coherer, in which the circuit was interrupted after each signal. He began work on a detector having a continuous circuit, which he developed in partnership with Edwin H. Smythe, who even helped him financially after De Forest was discharged from the laboratories. Test results of the new detector were unsatisfactory but promising enough to keep De Forest at work. He worked for the American Wireless Telegraph Co. of Milwaukee until pre-occupation with his detector again brought about his discharge.

Marconi's successful wireless transmission of signals fired De Forest's imagination, and he tried to put his new detector into use by organizing the De Forest Wireless Telegraph Co. in 1901. Stocks were sold, but no practical installations were made, and only law suits of various kinds resulted.

2 Saturday Evening Post, January, 1942.

De Forest tried to set up a wireless telegraph system of five stations for the U. S. Navy, which resented Marconi's policy of only leasing equipment, but the record static in the year 1905 made the system unsatisfactory and interrupted the work. During his work for the Navy, De Forest had tried to improve the Fleming diode detecting tube (patent 803,684, issued November 7, 1905) as a way out of litigation with Marconi and Fessenden, and to save the one-half of the current "leaking" from the filament to the plate. In one of a large number of experiments he inserted a third electrode in various positions, and he finally placed a grid between the filament and plate, thus producing the audion on which he filed a patent application, after weeks of effort to raise the then $15.00 filing fee. The patent on the three-electrode tube was issued February 18, 1908, No. 879,532 (Fig. 10).

At that time the affairs of the De Forest Wireless Co. were so involved financially and otherwise that De Forest withdrew his then-pending application on the audion. He organized the Radio Telephone Co. and made various efforts to find uses for his tube. He even made broadcasts, including some from the Metropolitan Opera House in 1910. He exhibited his experimental apparatus before five engineers of the Western Electric Co. but received no response for months. Bankers refused him loans, and his Yale classmates would venture a total of only $500. As late as November, 1913, De Forest was tried for using the mails to defraud by offering stock, as charged, "in a company incorporated for $2,000,000 whose only assets are the De Forest patents, chiefly directed to a strange device like an incandescent lamp, which he calls an audion, and which device has proved to be worthless." The jury debated for 13 hours before reaching a verdict of acquittal.

De Forest then took a job with the Federal Telegraph Co., where he worked on the problem of amplifying signals. Here, for the first time, he connected several of his tubes in series to get amplification. At that time long distance telephony was impossible, and De Forest took his tube and circuit to A. T. & T. Co., where its possibilities were recognized. De Forest's dealings with a series of promoters and promotional companies had, however, so clouded the title to his invention that several months of work were required before rights under the tube patent could be sold to A. T. & T. by his Radio Telephone Co. for $250,000, of which De Forest's share was $175,000. Additional rights were later purchased by A. T. & T. for $90,000, and the transatlantic telephone became a reality in 1915.

Later A. T & T. bought all of De Forest's patents and his vacuum tube inventions for a period of seven years. The purchase price which De Forest received was $250,000 and the right to manufacture equipment for amateur use and "for the distribution of music and news." De Forest had, however, also retained the right to license use of the audion to the Marconi Co. and he sold a license at a royalty of 80 cents per tube which brought him $160,000. However, that license became worthless when R. C. A. was formed with rights from A. T. & T.

De Forest admits that he has received four fortunes to date. But in 1913 he pawned his watch and his wife's ring for money with which to work on synchronizing speech with moving pictures. He succeeded in his talking movie work in 1923 (5 Journal of the Patent Office Society 270), but Hollywood was not interested, and four years later Fox bought the Case system for $1,500,000.

In 1914 De Forest lost his European patents for lack of $125 for renewal fees. In 1936 he went through brankruptcy, listing $104,000 of debts and $400 in assets. De Forest has received several honorary degrees, various medals, and numerous other tributes. He has approximately 175 patented inventions to his credit, but he makes a very modest living from the manufacture of diathermy machines under licenses from owners of other patents.

Sholes Typewriter, 1868

The typewriter and linotype are both means of communication, and as means for the dissemination of information they complement each other. Patent 79,265 was issued June 23, 1868 (Fig. 11), to C. Latham Sholes, Carlos Glidden, and Samuel W. Soule, all of Milwaukee, Wis. Sholes was collector of customs and he also operated a small printing shop in Milwaukee. He had already made other inventions, including a mail addressing machine and a numbering device. Sholes disclosed his numbering device to Glidden, who promptly asked, "If you can write numbers, why not letters?" After the discussion between Sholes and Glidden, it was decided to attempt the work with the aid of Soule who was a practical machinist.

Before the Sholes patent came a French patent, in 1833, showing a manually operated keyboard, United States Patent 15,164, to A. E. Beach, issued June 24, 1856, showing an almost modern typebar arrangement; and patent 18,504 to S. W. Francis, issued October 27, 1857, showing an ink carrying ribbon and a paper carriage. None of these patents, however, had line spacing or letter spacing means nor the principle of converging type bars, and none had a combination of all of the elements necessary to form a practical typewriter.

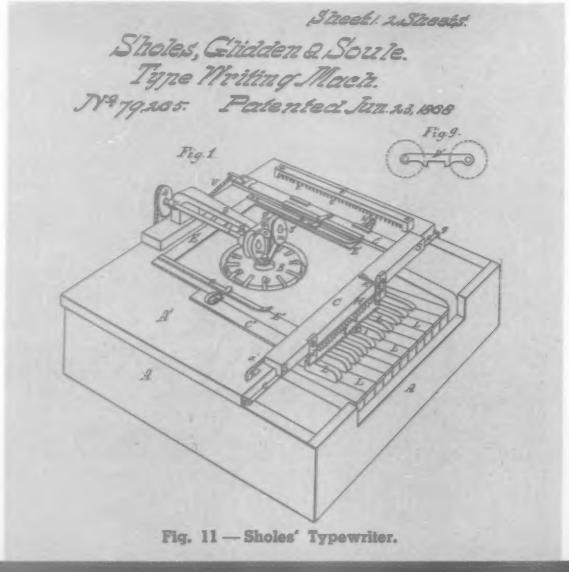


Fig. 11 — Sholes' Typewriter.

The first machine was finished late in 1867 and it was sold to Charles Weller, formerly a telegraph operator in Milwaukee, then a shorthand reporter in St. Louis. The machine proved practical, but required improvements. In five years there resulted substantially the modern keyboard arrangement, metal type bars set in good bearings, a rubber roller, its carriage, and other details. Most of the machines, however, broke down after steady use of a week or two.

Financial aid was given by James Densmore of Meadville, Pa., who was so impressed by a typewritten letter he received that he bought a one-fourth interest in the invention for the payment of expenses, without even inquiring what the expenses would be. Fifty machines were built from 1867 to 1873 at a cost of $250 each. When the reliability was still too poor and the cost was too high, it was suggested that the machines required manufacturing workmanship of the quality used in firearms.

Sholes and Densmore accordingly went to E. Remington and Sons, who made a proper mechanical design of the parts and manufactured the parts with the necessary precision. In the first year (1874) Remington sold 400 machines and offered to buy the patent. Sholes was no business man and he was not greatly interested in money so he sold his rights for $12,000 cash. The others, however, took a royalty and received many times $12,000 annually for the entire life of the patent.

Sales of typewriters languished until 1882 when the sales went into the hands of Wyckoff, Seamans and Benedict who sold 200,000 machines in 14 years. By 1886 the typewriter business had grown to such an extent that it overshadowed the Remington firearms business and thus became an industry in itself.

Mergenthaler's Linotype, 1890

The linotype was invented by Ottmar Mergenthaler and patented September 16, 1890, as Patent 436,532 (Fig. 12). Mergenthaler was born in Wurttemburg, Germany, in 1854. He came to the United States after serving a machinist's apprenticeship and in the United States made use of all the night schools available. Mergenthaler worked in a cousin's machine shop in Washington, where instruments were made for various government departments, and he soon became known for his ready grasp of the principles of new devices. The idea resulting in the linotype came from improving Charles G. Moore's machine for typing Senate reports on strips of paper and then transferring the justified strips to a lithographic stone for printing. Moore's machine proved unsuccessful, but Mergenthaler worked with the embossing of strips of paper into which metal might be cast. The paper-metal casting process proved to be unsuccessful, but it was the germ of the typecasting used in the linotype.

Prior to the invention of the linotype, all type had been cast in separate letters since Gutenberg's day of four centuries ago, and it had been set by hand or by typesetting machines such as that of J. W. Paige (Patent 547,860 issued October 15, 1895, on which $1,300,000 is said to have been spent). With the linotype, the amount of type set per man was five to ten times greater than that set by hand, the type faces were always new, the cost of buying and storing large quantities of factory type was eliminated, and the necessity for redistribution of the type back into the cases after use was abolished. The linotype was first used by the *Baltimore Sun* in 1885, and the *New York Tribune* installed linotypes in 1886. J. O. Clephane and Charles Moore formed the Typographic Co. to aid Mergenthaler in his work.

The Mergenthaler Linotype Co. was formed by a syndicate of newspaper men who spent hundreds of thousands of dollars to perfect, produce, and market the machine. Use of the linotype was resisted by printers' unions because of contractual limits on employment and output. Mergenthaler did not retain any interest in the company and thus did not materially share in the later financial success of the linotype. Mergenthaler's interest remained with the linotype, however, and he worked so hard improving his original machine (over 50 patented improvements) that his health failed by 1894, and he died an embittered man, from tuberculosis, five years later.

(To be concluded in next issue)

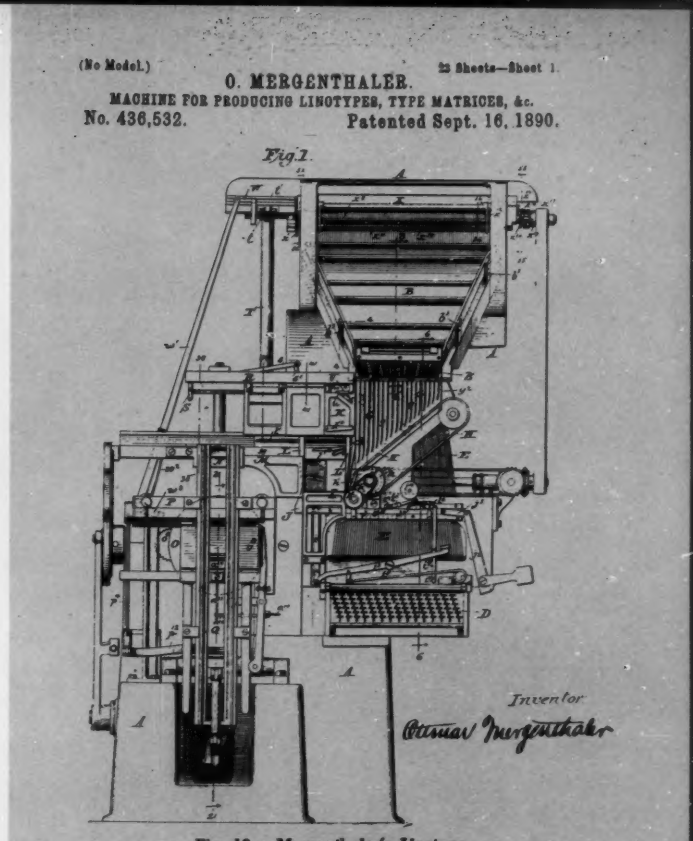
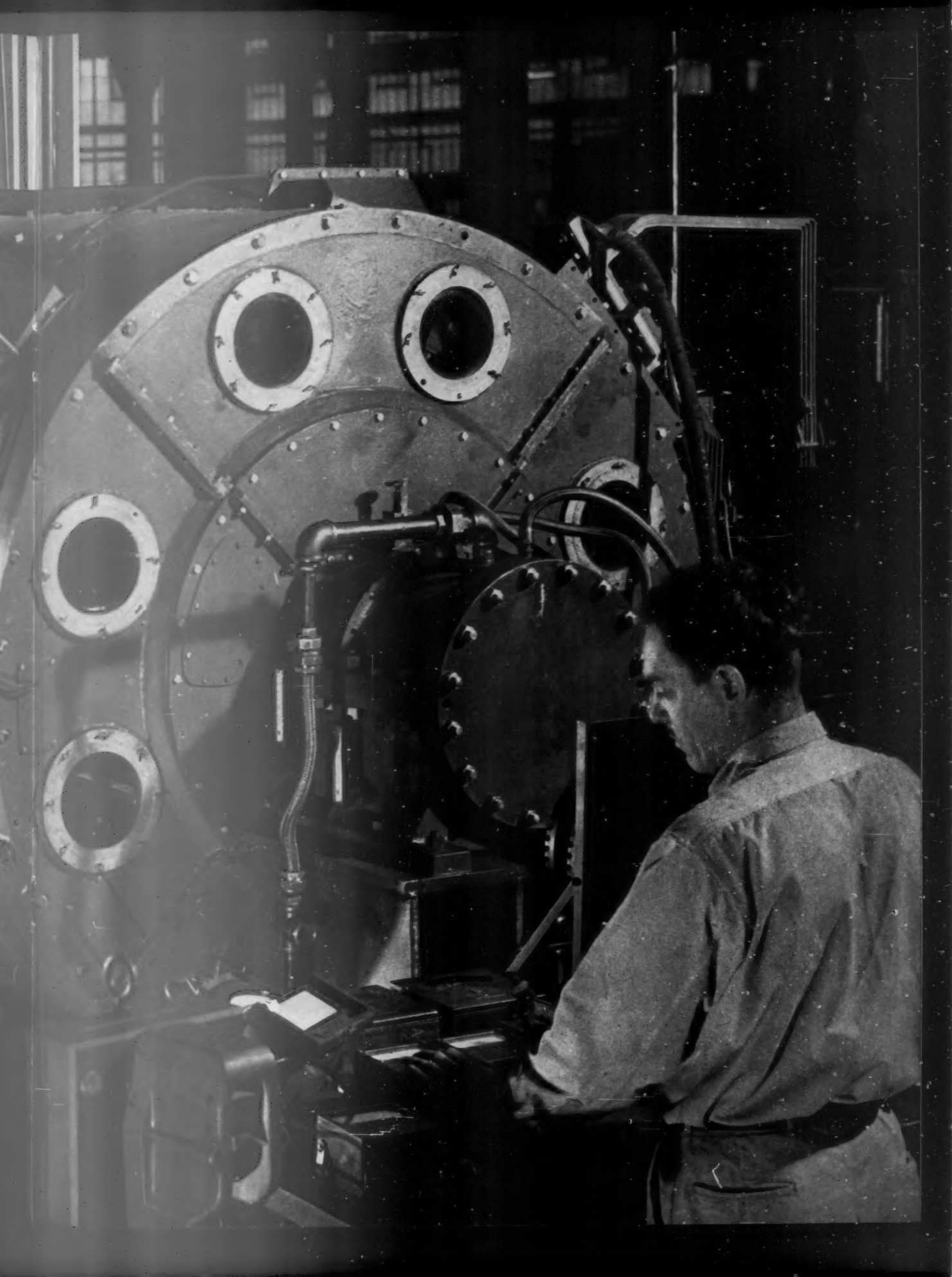


Fig. 12 — Mergenthaler's Linotype.

ON FOLLOWING PAGES: With this direct drive, 2,700 hp propulsion motor for a diesel-electric marine drive, reduction gears are eliminated from the propulsion system. The unit is shown on a full load test run, using the pump-back method. Location of this motor in the propulsion system is described in "Making Ships Go," on pages 30-34.



BRAZING WITH SILVER ALLOYS

When tin became one of the rare metals, the electrical industry had to look for solder substitutes. The "substitute"... silver alloy brazing ... turns out to be more efficient than the original soldering!

J. E. Petermann and E. H. Fredrick

ELECTRICAL DEPARTMENT • ALLIS-CHALMERS MANUFACTURING COMPANY

● The shortage of tin and other strategic metals has been a stimulus for the development of new and better methods of joining electrical conductors with less critical material. Most electrical joints used to be made with ordinary lead-tin solder, but now the newly developed method of brazing with silver alloys may supplant to a great extent the use of lead-tin solder even after the war. Greater mechanical strength, less bonding material, neater appearance, low manufacturing cost and simple technique are outstanding advantages of the new silver brazing process.

The term "silver solder" has been commonly used to denote joining metals with silver alloys. The term "solder" implies that the bonding material has a low melting point characteristic of the lead-tin alloys. To correct this impression, the term "silver brazing" is now preferred. Brazing is a group of metal-joining processes where the filler is a non-ferrous metal or alloy whose melting point is above 1,000° F, but lower than that of the metals or alloys to be joined. Silver brazing utilizes various silver alloys with melting points between 1,175 F to 1,600 F.

A good silver brazed joint requires the proper brazing alloy in its proper form, correct design and preparation of the joint, and a suitable means for heating. Brazing alloys for electrical connections usually contain silver, copper, and zinc in varying proportions, depending on the characteristics of the joint (Table I).

Forms of alloy

Silver brazing alloys are commercially available in strips in all widths and thicknesses down to .002 in.; in rods and wires down to 1/32 in., either square or round; and in powders from 20 to 150 mesh. Rod and wire is fed into joints where the molten alloy will flow subsequently through the joint by capillary action. Strips, rods, and wire are also preplaced in joints. Powdered alloy is limited to special operations where it is not practical to use the solid forms.

For maximum tensile strength in the joint it is necessary to keep the thickness of the brazing alloy between the parent metals less than .002 in. or .003 in. over the full area of the joined surfaces. Tests with a typical commercial silver brazing alloy joining two pieces of stainless steel showed a tensile strength of 130,000 psi with a .002 in. thick joint. Tensile strength decreases with a thicker joint, and in this case a joint .024 in. thick had a strength of only 48,000 psi. Accurate fitting is required to make a joint thickness of .002 in., but ordinarily high strength is not too imperative and a .010 in. joint thickness is satisfactory.

Butt, lap, scarf joints

The three common types of joint design are the butt joint, the lap or shear joint, and the scarf joint (Fig. 1). The butt joint (Fig. 1a) is very satisfactory if the butting edges are square and if clearances can be such that the brazing material is no thicker than .010 in. The scarf joint (Fig. 1b) has more bonding area than the butt type, and in general it is a much safer and stronger joint. Of the three types the lap joint (Fig. 1c) is the most versatile and best for general use because the length of the lap can be varied to give the desired strength and conductivity. A lap joint is more leakproof than any other type.

For a good brazed joint the parts have to be clean and free from oxidation, oil, and other foreign material. Possibly the most effective method of cleaning parts to be brazed is by mechanical means, such as filing, grinding, or polishing with fine emery cloth.

The old familiar borax and boric acid fluxes are more or less obsolete for low-temperature silver alloy brazing. A good flux must protect the metals to be joined and the molten brazing alloy from oxidation and at the same time dissolve any oxides which may form during brazing. The flux should also assist in causing the molten alloy to flow. Several commercial fluxes now on the market will do all these things.

Heating the joint

The proper application of controlled heat is one of the major factors in making a successful silver brazed joint. The electrical resistance method is probably the most satisfactory. A modern war worker using a

Grade	Chemical Composition Percent					Melting Point °F	Flow Point °F	Specific Gravity As Cast	Uses
	Ag	Cu	Zn	Cd	P				
1	10	52	38	..	..	1,510	1,600	8.55	Joining iron, steel, or any non-ferrous metals that will not be melted or damaged by heating to 1,600 F. This high strength malleable and ductile alloy is low in cost. Recommended for joints to be heat-treated at relatively high temperatures.
2	20	45	30	5	..	1,430	1,500	8.80	For joining copper, copper base alloys, nickel silver, steel, and iron.
3	30	38	32	..	..	1,370	1,410	8.86	Same uses as Grades 1 and 2.
4	40	36	24	..	..	1,330	1,445	9.11	For steel, iron, copper, copper base alloys, and nickel silver. Grade 5 can be used with monel if parts are not heated above 1,400 F. Grade 6 is most popular.
5	45	30	25	..	..	1,250	1,370	9.15	
6	50	34	16	..	..	1,280	1,425	9.37	
7	60	25	15	..	..	1,260	1,325	9.52	For small parts where low flow point is advantageous. Better for monel than Grade 5 (1,400 F is maximum for monel joint).
8	70	20	10	..	..	1,335	1,390	9.76	Higher ductility and corrosion resistance than lower grade alloys.
9	72	28	..	..	..	1,435	1,435	9.95	Silver copper eutectic used when zinc and chromium are objectionable.
10	80	16	4	..	..	1,360	1,460	10.05	Extremely ductile and malleable.
11	15	80	..	..	5	1,190	1,300	8.45	Recommended only on copper or copper base alloys. Most satisfactory for copper. Phosphorus content makes it self-fluxing.
12	50	15.5	16.5	..	18	1,160	1,175	9.49	Free-flowing property at 1,175 F makes this an all-around alloy for steel, stainless steel, iron, copper, copper base alloys, nickel and nickel alloys. Best alloy for monel.

TABLE I — Physical properties of alloys for silver brazing.

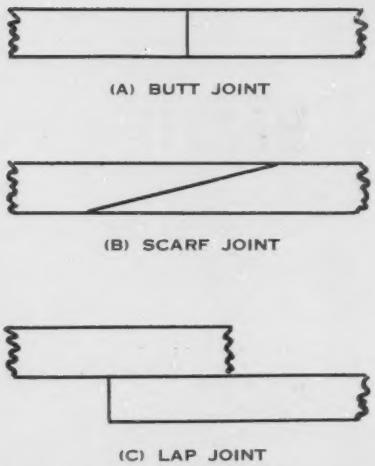


Fig. 1 — Joints used in silver brazing. The lap joint is the simplest to make and the most popular.

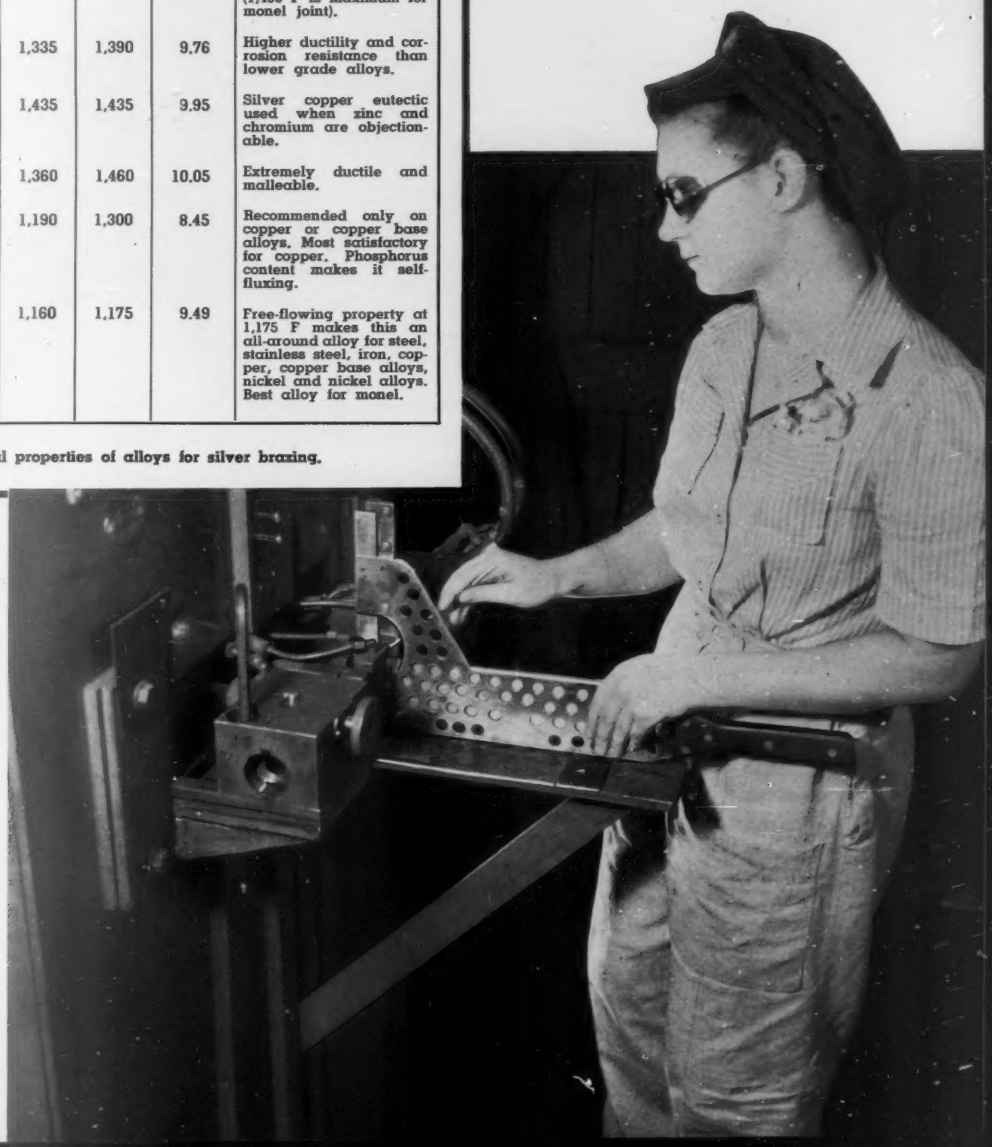


Fig. 2 — Machine for brazing commutator bars to risers. Current passing through the water-cooled carbon electrodes automatically heats the connection, and the operator feeds in a little silver brazing alloy.

Fig. 3a — Connections made on a squirrel-cage rotor by riveting and brazing.

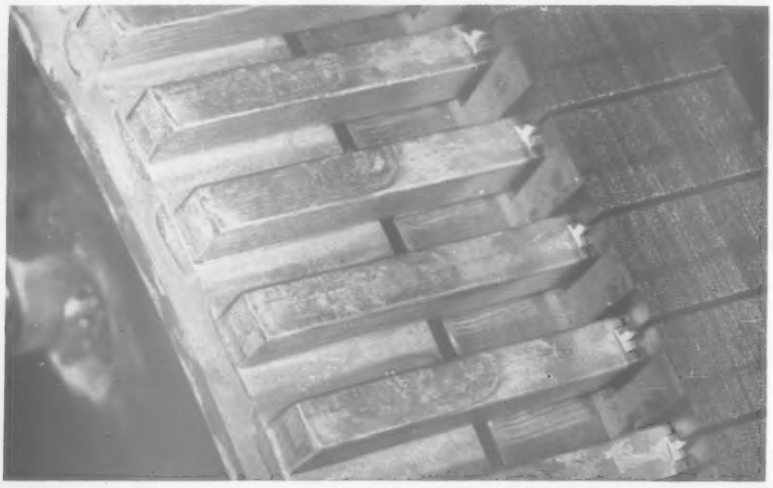
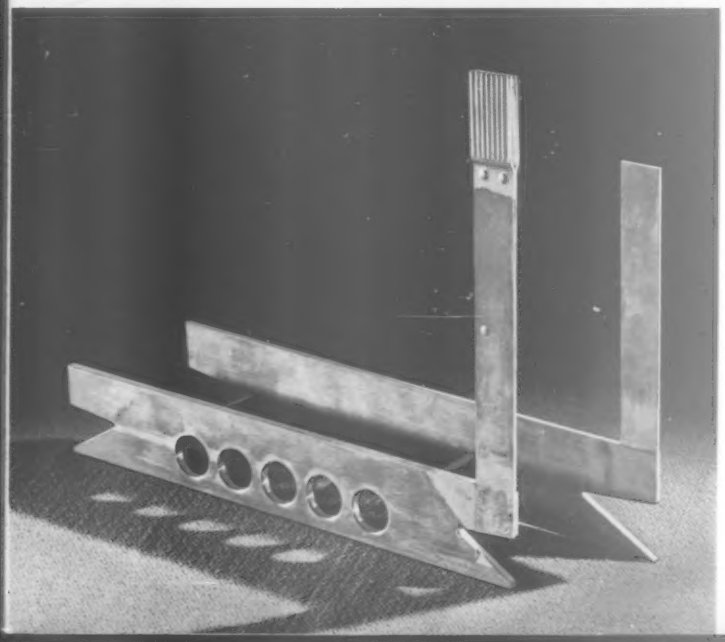


Fig. 3b — Modern silver brazing, using the resistance method, produced these connections on a squirrel-cage rotor. Mechanical strength and good electrical conductivity are obtained.

Fig. 4 — Silver brazed end connections on the stator of an a-c machine.



resistance brazing unit to assemble a riser to a commutator bar is shown in Fig. 2. The machine is an adjustable voltage transformer that feeds current to a pair of jaws faced with carbon blocks. The pieces to be brazed are clamped between the carbon blocks of the jaws, and the flow of current through the carbon and metals creates the heat for brazing. The operator merely inserts the work between the jaws and closes them; and when brazing temperature has been reached, she feeds a little brazing alloy into the joint. The jaws are water cooled to prevent overheating the parts supporting them and also to dissipate the stored heat during the off part of the cycle.

A similar brazing unit which is portable is particularly useful for making connections on the stator coil ends of a-c stators and in joining commutator risers to the armature coil ends on d-c armatures. A pair of water-cooled tongs clamp the parts, apply pressure and heat to the joint simultaneously, which makes this method very versatile.

In production brazing on a large scale, a furnace method has proven very successful. Accurate control of temperature is easy, but it is essential that the atmosphere in the furnace be of a reducing (oxygen-absorbing) character. The brazing material is preplaced in the joint which is usually designed especially for the brazing operation. It is suggested that, in either furnace or gas torch brazing, oxygen-free copper be used to avoid the possibility of hydrogen embrittlement of the parts.

Brazing with torch

Possibly the most common method of brazing for all-

Fig. 5 — Commutator bars soldered (left) and silver-brazed (right) to risers. Soldered riser requires rivets for strength.

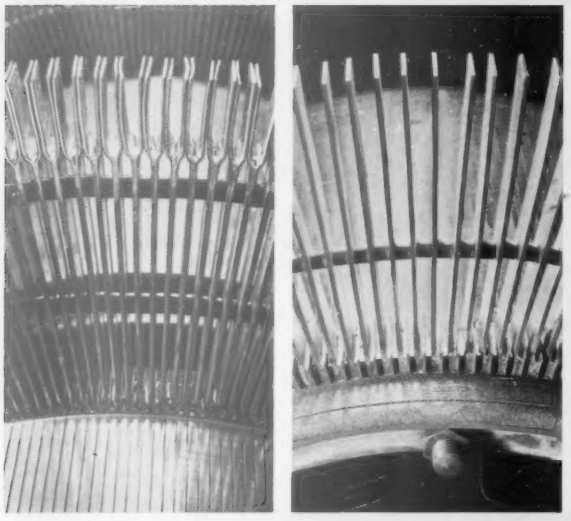


Fig. 6 — Commutator risers prepared for soldering (left) and silver brazing (right) to armature coil ends of a d-c generator.

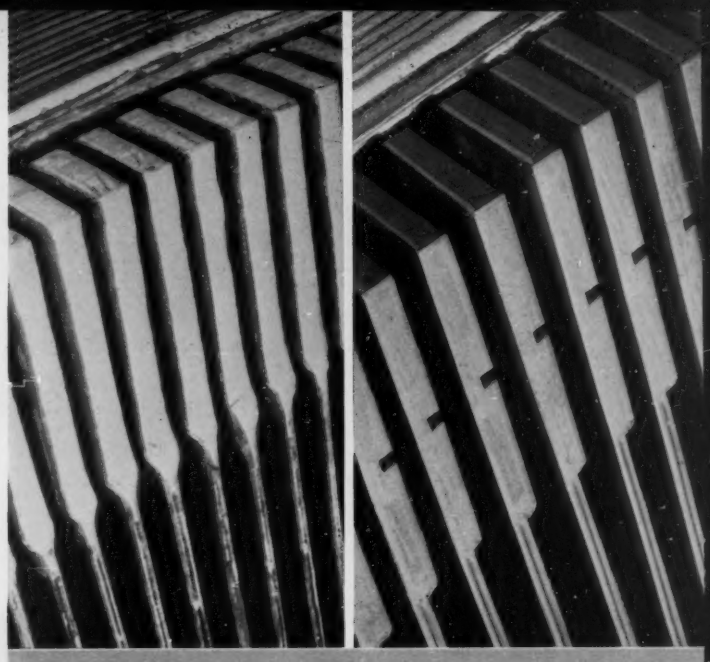


Fig. 7 — Finished connections of commutator risers to armature coils made by soldering (left) and silver brazing (right).

around use is the gas flame or torch method. Various gases are used, the most popular being oxy-acetylene, which provides a high-temperature flame having reducing characteristics. The temperature of the flame can be readily controlled by throttling, but the operator has to use his judgment in estimating the actual temperature of the parts. A good indication of temperature is the action of the flux, which melts a short time before brazing temperature is reached.

These methods of brazing are by far the most popular, but for special cases others are available, such as dipping parts in molten metal of a chemical bath, arc brazing, and heating by electrical induction.

In the manufacture of electrical equipment, great progress has been made in the use of silver brazing to replace the old familiar soldered, or riveted and soldered joints. In the old construction (Fig. 3a) the squirrel cage winding was first riveted to the end ring and then brazed. The rivet was intended to provide the mechanical strength while the silver alloy provided a good conducting path. In the modern construction (Fig. 3b) both mechanical strength and good electrical conductivity are obtained with the joint brazed by the resistance method of heating and one of the new low-temperature silver brazing alloys. The manufacturing operations have been simplified by eliminating the rivet. A silver brazed joint applied to lead and phase connections on the stator winding of an alternating current machine is shown in Fig. 4. These connections were formerly soldered with lead-tin alloys.

Possibly one of the most outstanding developments of silver brazing has been in the assembly of direct current armatures. The soldering (with lead-tin) of the risers to the commutator bars and the risers to the coil ends has always been a tedious operation and subject to manufacturing imperfections. A comparison between the soldered-and-riveted type of joint formerly used and the newer brazed joint is shown in Fig. 5. The brazed joint is far simpler and neater.

Silver brazing has been so far developed that all connections on the armatures of direct current machines now can be successfully made with this method. Fig. 6 shows a comparison between commutators arranged for lead-tin soldering and for brazing of the risers to the coils. The completed armatures are shown in Fig. 7.

Separating joints

One of the first questions usually asked about silver brazing is, "How do you separate the joints once they are made?" The process of opening a silver brazed joint is not much harder than opening a lead-tin soldered joint; either can be readily taken apart by applying the proper amount of heat. The higher temperature required to melt the silver alloy is an advantage, because the joint is less likely to part accidentally.

The shortage of tin caused by war conditions has been considered a manufacturing hardship, but real American ingenuity again came forward to provide a way to minimize the use of tin in the manufacture of electrical machinery. Not only has the vital material been largely displaced, but at the same time a better method of making electrical connections has been developed. The higher melting point of the silver alloys has increased the safety factor in many machines which formerly were subject to breakdown by accidental overheating of the soldered joints, especially on rotating parts. The cost of the silver alloy is considerably higher per pound than the normal price of lead-tin solder, but the small quantity involved in making a silver brazed joint and the saving in manufacturing cost makes silver brazing competitive with the conventional solders.

COMPACT BREAKER WITH BIG CAPACITY

Breakers built for scores of high current interruptions without maintenance have high "integrated duty" capacity. Here is what a new 150,000 kva air blast breaker can do . . . without contact renewal!

P. L. Taylor and A. C. Kelle

BOSTON WORKS • ALLIS-CHALMERS MANUFACTURING COMPANY

● In the past it has not been feasible to build power circuit breakers capable of many repetitive fault operations at high currents without maintenance and contact renewal. The evident need for breakers capable of scores of high current interruptions between maintenance periods, which are at the same time easy and economical to maintain, has stimulated the development of a new circuit breaker of oil-less design. This has been made possible by further development of the inherent characteristics of the axial air blast interrupter.

Small physical size

The new air blast breaker is comparable in size and shape to the common frame indoor oil circuit breaker of the same rating. The arrangement of the terminals is the same as for the equivalent oil circuit breaker and the supporting framework is arranged to permit complete enclosure if required.

A 600 ampere, 5 kv, 150,000 kva, 37,500 maximum ampere interrupting capacity breaker of the new design, equipped with plug type primary and secondary terminals for vertical lift mounting is shown in Fig. 1.

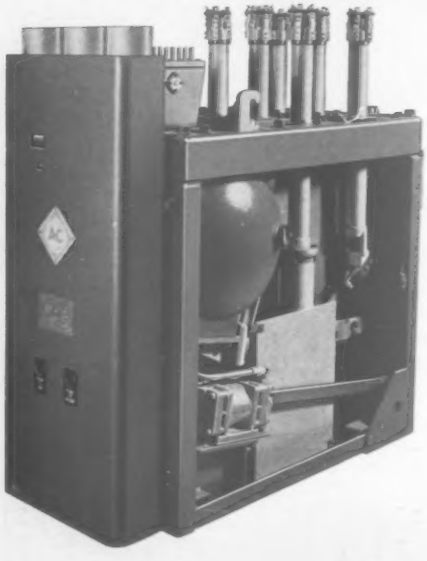


Fig. 1—New small size air blast circuit breaker, rated 600 amperes, 5 kv, 150,000 kva, for metalclad switchgear.

The unit has a structural steel frame in which are mounted the bushings, interrupting chambers, isolating disconnects, and a compressed air tank and air ducts, together with the necessary pneumatic operating and electrical control means.

The schematic diagram of a single pole of this breaker is shown in Fig. 2. The main electrical circuit is from T_1 downward through arcing and auxiliary contacts L and M, up through the shell B, through isolating contacts D, and up to terminal T_2. The air blast circuit is from the tank through blast valve A and manifold K to contact chamber B, thence through orifice contact M, interrupting chamber W, and exhaust tube C.

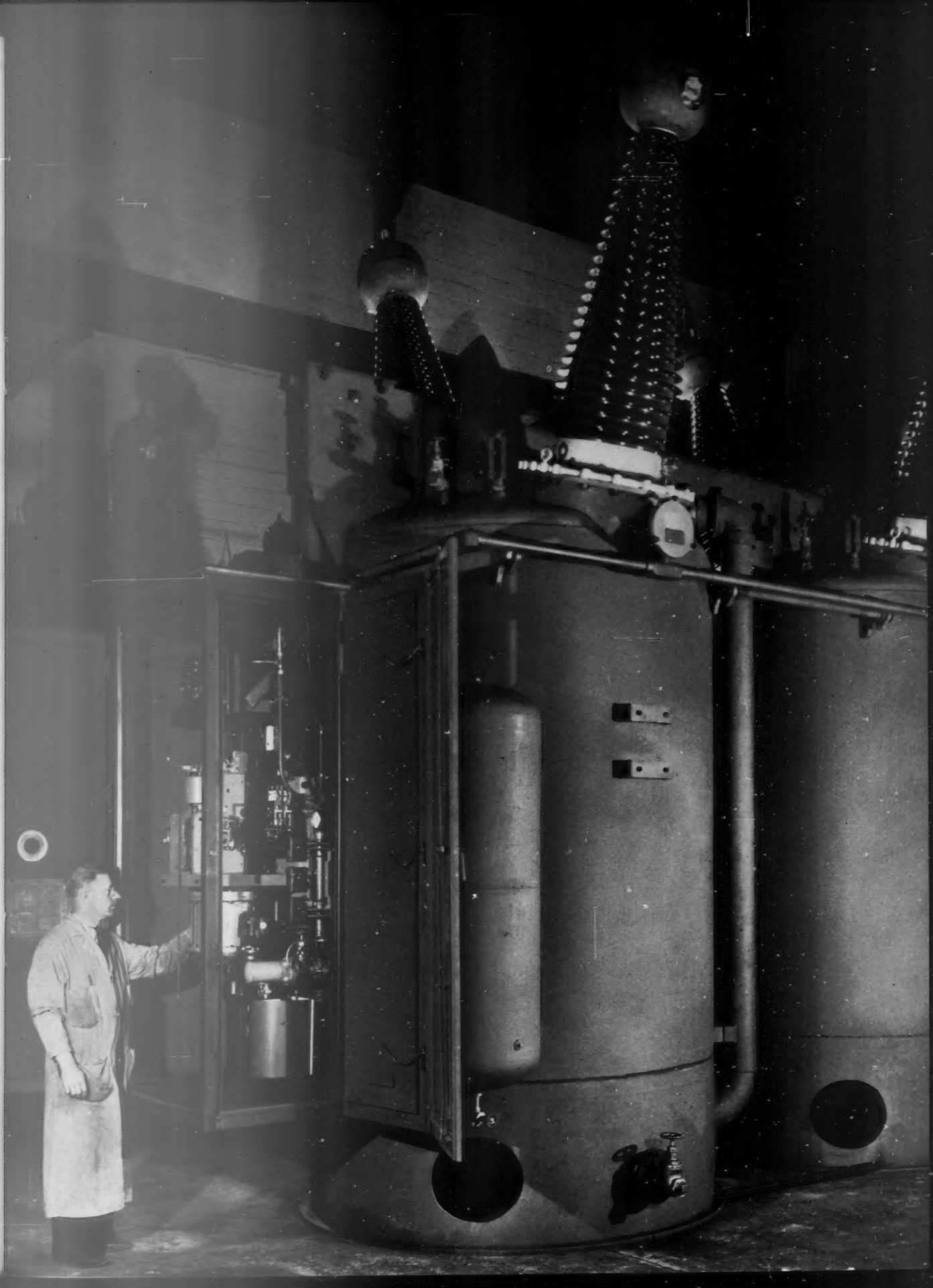
High-speed opening

The legend of Fig. 2 identifies major parts and describes their function. The breaker is closed by pneumatically closing the disconnect contacts. It is opened by opening the air blast valve, thus releasing an air blast which opens the arcing and auxiliary contacts and extinguishes the arc. The disconnect contacts are then pneumatically opened, the air blast is cut off, and the arcing and auxiliary contacts are reclosed, thus completing the opening cycle. Air dump valves on the disconnect operating cylinder permit high speed close-open and open-close operation. All contacts are readily accessible for inspection and can be easily and quickly replaced.

These new breakers have a high integrated duty capacity, yet they must fit within the restricted space normally provided for low interrupting kva, high interrupting current breakers to make them suitable for installation in metalclad switchgear and other restricted spaces. To accomplish this an improved air blast interrupter of the axial blast type has been developed (Fig. 3).

The interrupting device has a contact chamber containing a piston-operated moving contact assembly,

AT RIGHT: An air operator speeds reclosing on this pneumatically operated, outdoor oil circuit breaker, rated 2,500,000 kva interrupting capacity, 1,200 amps, 161,000 volts.



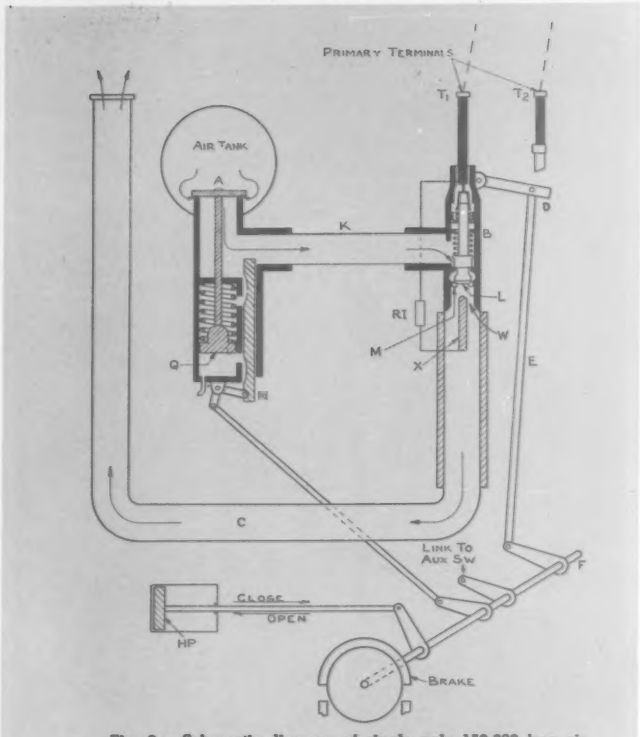


Fig. 2 — Schematic diagram of single pole 150,000 kva air blast circuit breaker (breaker open), showing operation.

EXPLANATION

A — Air blast valve. When opened compressed air flows through K to contact chamber B — opens arcing contacts L — flows through contact M interrupting chamber W and exhaust tube C.

B — Contact chamber.

C — Exhaust tube.

D — Disconnect (or isolator) contact — opens after L is open.

E — Insulated operating links.

F — Breaker shaft — operated by air piston Hp — connected to disconnect D, auxiliary switches, and slide valve N.

Hp — Disconnect operating piston — operates shaft F, disconnects D, auxiliary switches, and slide valve N.

K — Air distribution manifold.

L — Movable arcing contact — blown open by air blast — spring reclosed after D opens.

M — Stationary arcing contact.

N — Slide valve — operated from shaft F — when D reaches "open" position valve vents air on bottom of Q to atmosphere and admits air from K to top of Q to close A and shut off air blast.

T_1, T_2 — Primary terminals — primary circuit is through T_1, L, M, B, D to T_2.

Q — Blast valve piston — operates blast valve A.

RI — Non-inductive resistor — controls recovery voltage transient.

W — Interrupting chamber.

X — Resistor electrode.

which carries movable auxiliary and arcing contacts, cooperating stationary contacts, including an orifice type arcing contact, and a refractory throat separating the stationary auxiliary and stationary arcing contacts. The interrupting chamber is located below the orifice of the stationary arcing contact.

When compressed air is admitted into the contact chamber, it acts upon the piston on the upper end of the moving contact assembly to push the assembly up. First, the auxiliary contacts part and then the arcing contacts separate, simultaneously uncovering an orifice in the stationary arcing contact to permit the main air blast to flow through.

Interruption at first zero

As the arc is drawn between the arcing contacts, the blast of compressed air immediately drives the arc terminal on the stationary contact through the orifice; and centralizes the arc terminal on the movable contact and its appended arc filament in the orifice, so that both terminal and filament are enveloped by the compressed air stream. The portion of the arc which is propagated into the interrupting chamber below the orifice is extended by the swiftly flowing compressed air. As the current approaches its cyclic zero, the highly effective diffusion and cooling, produced in the arcing zone by the sudden expansion of the compressed air as it leaves the orifice, causes rapid deionization of the arc path, preventing re-ignition of the arc after the current zero, thereby achieving immediate circuit interruption. The arc products are cooled and dispersed in the air which passes out through the exhaust tube.

In most cases, a non-inductive arc-shunting resistor (shown in Fig. 2) is connected between breaker terminal and a resistor electrode in the interrupting chamber. As the arc is extended below the orifice, it is forced into contact with the resistor electrode and the resistor is automatically connected in parallel with the section of the arc between the movable arcing contact and the resistor electrode. As the fault current approaches zero the paralleling arc becomes unstable and is extinguished. A relatively small current continues to flow through the resistor and its series arc for one-quarter cycle or less, during which time a large part of the energy stored in the external circuit reactance is dissipated, so that this energy cannot contribute to the production of a high transient voltage. Because of the improvement of current and voltage zero relation, when the low resistor current is interrupted at its zero, the normal frequency component of recovery voltage also has a lower value.

Separate arcing and disconnecting contacts connected in series separate the interrupting and isolating functions to permit each contact to be designed only for its specific function. The arcing contact has a short stroke which helps keep the initial arc energy low, and provides for effective air blast and proper arc propagation. The arrangement and high operating speed of the isolating disconnect contacts permit the closing of high currents in air with negligible deterioration of the contacts. The location of the isolating contacts completely apart from the interrupting unit permits absolute isolation of the circuit, eliminating the hazards of shunting leakage surfaces.

Balanced design

The superior performance of this new interrupter is principally a result of the high degree of limitation and control of arc energy and arc products, especially in the contact chamber above the orifice, during and immediately after arc inception. The short arcing contact break distance and silver-tungsten surfaced contacts result in a minimum initial arc energy. The unique refractory throat, contact arrangement, and the air blast provide for effective control of the

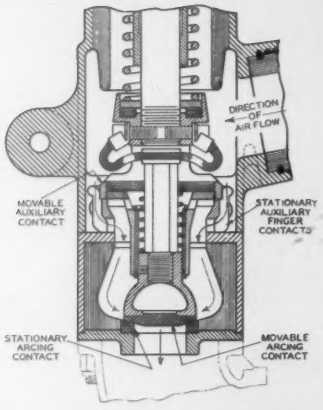


Fig. 3—Final design of interrupting unit, with refractory throat and tungsten-silver surfaced arcing contacts.

arc and arc products above the orifice by immediate and rapid propagation of the arc terminal on the stationary arcing contact through the orifice, and also by the limitation and control of metallic emission. The combination results in *the maximum of control over the minimum of arc energy*.

The balanced design of this interrupting device is the result of extended development. Its adaptation to the breaker described provides reliable, effective, high speed breaker operation with consistent "half-cycle" interruption and heavy integrated duty capacity throughout the complete range of its interrupting current and voltage and kva rating, as shown by the typical test data.

Air supply system

The compressed air equipment required for the operation of air blast breakers is the counterpart of the battery or transformer and rectifier equipment required for solenoid-operated breakers. The capacity and arrangement of the air supply and storage system can be varied to meet the requirements of the number of breakers and frequency of operation in the particular installation. A typical air supply unit arranged for installation in metalclad switchgear is shown in Fig. 4.

Test data

During the development and proof-testing of the new breaker and its interrupting device, thousands of tests were made to check its interrupting ability at high integrated duty capacity. Typical test data taken under a variety of conditions shows the performance of this new breaker.

An indication of the high integrated duty capacity of this breaker can be had from Table I, which is the summary of a series of 100 interrupting tests made with a single set of arcing contacts at currents ranging from 10,000 to 40,000 rms amperes. All tests were made at or below rated minimum air blast pressure. The arcing contacts used for this test series are shown in Fig. 5.

Most of the tests summarized in Table I were close-open tests. Oscillograms (Fig. 6) showed that the peak inrush currents closed on some of these tests were as high as 115,000 amperes. The isolating contacts have repeatedly closed against peak inrush currents up to the maximum current obtained without appreciable burning, indicating that hundreds of high current closures without maintenance can be expected.

The ability of the arcing contacts to "take it" on repeated high current interruptions is shown by the

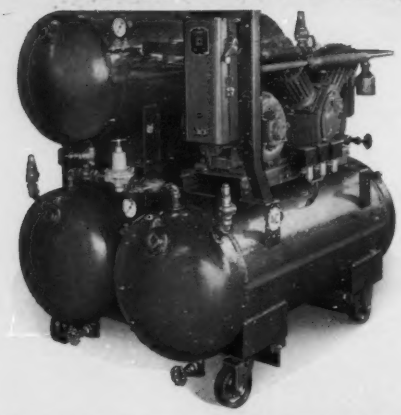


Fig. 4 — Typical two pressure air supply system with compressor.

Number of Shots	RMS Current Interrupted, Amps.	Duty	Arcing Time Cycles*
30	10,000-15,000	CO	0.05 to 0.4
21	15,000-20,000	CO	0.04 to 0.4
15	20,000-25,000	CO	0.05 to 0.6
21	25,000-30,000	CO	0.05 to 0.7
4	30,000-35,000	CO	0.1 to 0.45
9	35,000-41,000	CO	0.1 to 0.55

* Arcing time is measured in time units of one cycle or one-sixtieth of a second. All arcing times are one current loop or less after adequate parting of the arcing contacts.

TABLE I — Summary of series of 100 single-phase interrupting tests made at or below minimum operating pressure at currents ranging from 10,000 to 41,000 amperes on a single set of contacts, shown in Fig. 5. Test voltage 2,000 to 2,300 volts across single pole.

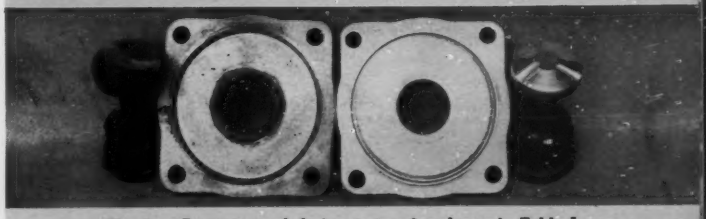


Fig. 5 — Contacts used during test series shown in Table I. Left: after tests at 10,000 to 41,000 amps.; right: unused.

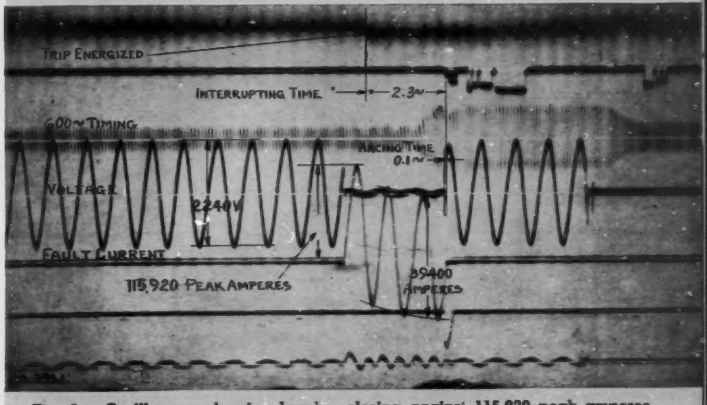


Fig. 6 — Oscillogram showing breaker closing against 115,920 peak amperes.

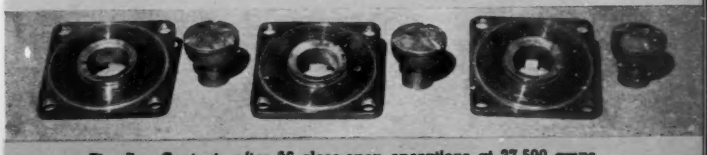


Fig. 7 — Contacts after 26 close-open operations at 37,500 amps.

Test No.	Duty	RMS Current Interrupted			Arcing Time—Cycles		
		A	B	C	A	B	C
118-301	CO	6,000	6,010	5,540	0.1	0.05	0.1
-302	CO	34,200	36,000	33,200	0.3	0.2	0.15
-303	CO	40,400	43,900	41,700	0.2	0.3	0.05
-304	CO	44,600	48,100	46,900	0.2	0.25	0.05
-305	CO	44,200	47,700	46,900	0.25	0.3	0.05
-307	CO	27,800	28,600	28,400	0.1	0.1	0.25
-311	CO	No film—Approx. 45,000 Amps.					
-312	CO	45,000	49,100	46,900	0.2	0.3	0.05
-314	O	44,600	48,800	46,500	0.25	0.25	0.1
-315	O	44,600	No film		0.3	No film	
-316	O	45,500	49,500	47,200	0.25	0.05	0.2
-317	O	45,000	48,800	47,200	0.25	0.1	0.25
-319	O	47,100	50,200	47,600	0.25	0.05	0.2
-320	O	47,100	51,000	47,600	0.2	0.05	0.25
-321		47,100	51,300	48,200	0.05	0.25	0.25

TABLE II — Data on series of three-phase interrupting tests with final design of 150,000 kva interrupter shown in Fig. 3 at currents up to 50,000 amperes on a single set of contacts.

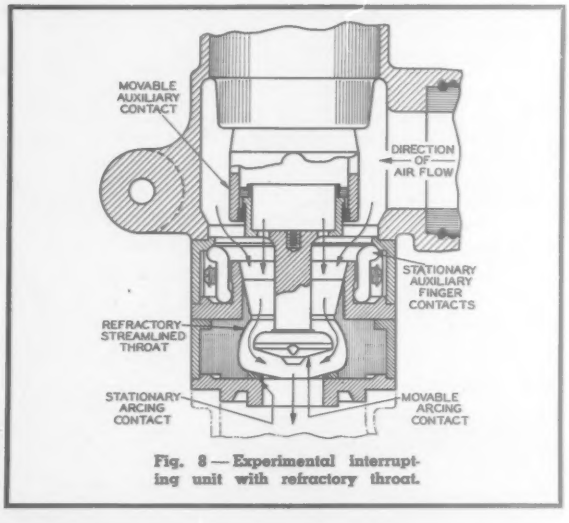


Fig. 8 — Experimental interrupting unit with refractory throat.

condition of the contacts in Fig. 7, after a series of 26 close-open tests at the maximum rated interrupting current of 37,500 amperes at 2,300 volts. Table II shows the data on a series of three-phase tests at 40,000 to 50,000 amperes. The arcing times on these tests, made at currents up to 135 percent of maximum current rating, were all less than one-half cycle.

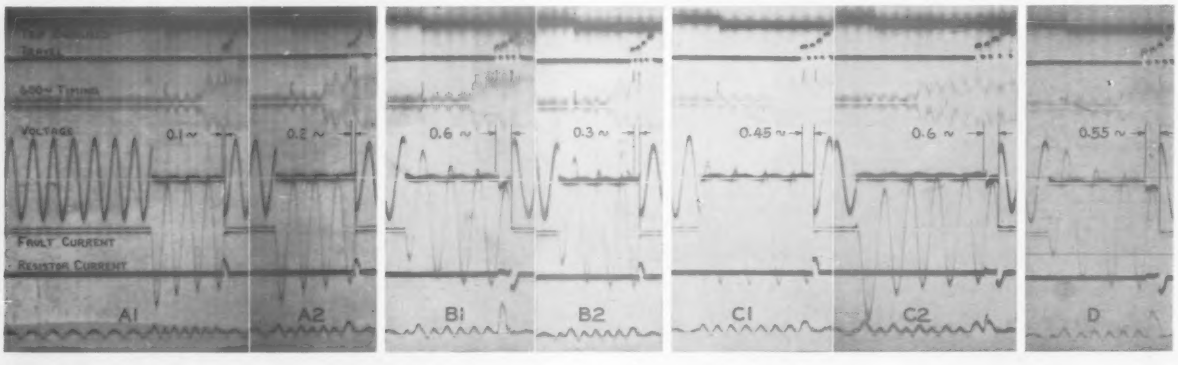
Many tests have also been made at low currents down to a fraction of an ampere. Consistent half-cycle interruption was obtained throughout the current range. This straight-line arcing time characteristic is not obtainable with other types of breakers.

Reduced pressure results

The performance of the breaker on repeated tests at reduced air blast pressure is shown by the series of 25 close-open interrupting tests in Table III. These tests were made with the final experimental interrupter in Fig. 8 at currents from 35,000 to 40,000 amperes, at 2,300 volts, single phase, with a single set of arcing contacts, and at reduced air pressures ranging from 110 down to 80 psi. Even at these low air pressures the arcing times were all less than one current loop after adequate parting of the arcing contacts. All of these shots are at or above the maximum rated interrupting current of the breaker. Fig. 9 shows a series of typical oscillograms taken during these tests.

The test data so far has stressed breaker performance at high currents, and at reduced air blast pressure, to demonstrate the ability of the breaker to "take it" at the highest arc energies to which it may be subjected. Numerous tests were also made at operating voltages in excess of the breaker rating. Table IV shows a series of three-phase over-voltage tests at 5,900 and 7,900 volts on the 5 kv breaker. At 5,900 volts, the rated 150,000 kva interrupting capacity of the breaker was exceeded by a considerable margin.

It will be noted from the test data and oscillograms, in every case taken under extreme duty conditions, that consistent interruption at the first current zero following adequate parting of the arcing contacts (maximum one current loop arcing time) was obtained throughout the range up to far beyond the maximum rated interrupting voltage, current, and kva.



Current Interrupted 39700 Amps.	38000 Amps.	38000 Amps.	38000 Amps.	39000 Amps.	38000 Amps.	38000 Amps.
Restored Voltage Across Pole Unit 2070 Volts	1880 Volts	2070 Volts	1880 Volts	2070 Volts	1810 Volts	2070 Volts
Air Pressure 110 Lbs.	103 Lbs.	100 Lbs.	94 Lbs.	90 Lbs.	84 Lbs.	80 Lbs.
Duty Cycle	CO-15 sec.-CO		CO-15 sec.-CO		CO-15 sec.-CO	CO

Fig. 9 — Typical test oscillograms from Table III at 2,300 volts across a single pole and with reduced air pressures of 110 to 80 psi. (Fig. 3 interrupter.)

Long contact life

The test data shows what this breaker can do under all conceivable conditions, much more severe than are likely to be encountered in service. Its "take it" ability is demonstrated on repetitive operation at assorted currents up to maximum rating, on extremely high inrush currents, on repetitive operation at currents in excess of maximum rating, at maximum current rating and reduced air blast pressure, and at operating voltages in excess of rating.

New ways have been found to augment the rate of ion diffusion and control metallic emission and its effects so that these new axial air blast breakers (even in small physical sizes where space limitations impose severe penalties) are capable of interrupting the highest short circuit current to which they may be subjected with a maximum arcing time of one current loop. Furthermore, they offer exceptional integrated duty capacity with low maintenance requirements even at these high currents.

The tests show that this air blast breaker, equipped with the improved interrupter, will interrupt scores of faults, without maintenance, at currents up to 50,000 amperes (over 130 percent of maximum interrupting current rating) in one-half cycle or less. This implies that, on the average application, the original arcing contacts will never have to be replaced as long as the breaker remains in service.

Test No.	Duty	Pressure P. S. I.	Test Voltage (Single Phase)	RMS Current Interrupted	Arcing Time Cycles**	Breaker Time Cycles
109-327.1*	CO-15 Sec.	110	2,230	39,700	0.1	3.0
-327.2*	-CO	103	1,940	38,000	0.2	3.2
-328.1	CO-15 Sec.	110	2,230	36,300	0.5	3.4
-328.2	-CO	103	1,940	39,700	0.4	3.2
-329.1	CO-15 Sec.	110	2,230	38,800	0.2	3.1
-329.2	-CO	103	1,940	37,200	0.3	3.3
-330.1	CO-15 Sec.	110	2,230	38,800	0.1	2.9
-330.2	-CO	103	1,940	38,800	0.35	3.45
-331.1	CO-15 Sec.	110	2,230	38,800	0 5	3.5
-331.2	-CO	103	1,940	38,800	0.5	4.7
-332.1	CO-15 Sec.	110	2,230	37,300	0.6	3.2
-332.2	-CO	103	1,940	38,000	0.15	3.15
-333.1	CO-15 Sec.	110	2,230	39,700	0.3	3.3
-333.2	-CO	103	1,880	37,500	0.2	3.2
-334.1	CO-15 Sec.	110	2,230	39,800	0.2	2.8
-334.2	-CO	103	1,940	38,800	0.25	3.25
-335	Calibration					
-336.1*	CO-15 Sec.	100	2,230	38,000	0.6	3.6
-336.2*	-CO	94	1,940	38,000	0.3	3.2
-337.1	CO-15 Sec.	100	2,230	38,800	0.25	5.25
-337.2	-CO	94	1,940	36,300	0.6	3.8
-338.1	CO-15 Sec.	90	2,230	38,900	0.6	3.7
-338.2	-CO	84	1,940	37,400	0.55	3.75
-339.1*	CO-15 Sec.	90	2,230	39,000	0.45	3.55
-339.2*	-CO	84	1,880	36,000	0.6	5.4
-340	Calibration					
-341*	CO	80	2.230	38,000	0.55	3.55

* Oscillograms of these tests are shown in Fig. 7.
** Arcing time is measured in units of one cycle or one-sixtieth second. All arcing times are one current loop or less after adequate parting of the arcing contacts.

TABLE III — Extended series of single-phase interrupting tests at low air pressure using final experimental 150,000 kva interrupter shown in Fig. 8.

Test No.	Duty	Nominal Test Voltage	RMS Current Interrupted			3-Phase Kva Interrupted	Arcing Time — Cycles		
			A	B	C		A	B	C
118-281.1	CO-15 Sec.	5,900	26,100	27,600	76,600	261,600	0.1	0.35	0.2
.2	CO	5,900	25,700	26,800	26,600	228,000	0.25	0.15	0.3
282.1	CO-15 Sec.	5,900	25,200	26,600	25,500	249,000	0.2	0.3	0.1
.2	CO	5,900	24,800	26,200	25,800	223,500	0.2	0.33	0.2
283.1	CO-15 Sec.	5,800	24,800	26,500	26,200	248,100	0.3	0.1	0.25
.2	CO	5,800	24,400	26,200	25,500	223,500	0.25	...	...
284.1	CO-15 Sec.	5,800	24,800	26,800	25,800	254,100	0.4	0.2	0.15
.2	CO	5,800	24,800	26,600	25,800	226,800	0.3	0.1	0.25
289.1	CO-15 Sec.	7,400	9,670	10,600	10,700	129,000	0.25	0.2	0.3
.2	CO	7,400	9,670	10,300	10,300	116,400	0.15	0.3	0.35
290.1	CO-15 Sec.	8,100	10,630	11,500	11,200	154,500	0.3	0.5	0.3
.2	CO	8,100	11,000	11,300	11,300	140,100	0.3	0.5	0.5
291.1	CO-15 Sec.	7,900	10,200	10,800	10,300	142,500	0.15	0.3	0.2
.2	CO	7,900	10,430	11,100	10,550	137,400	0.35	0.45	0.2

TABLE IV — Series of three-phase interrupting tests on 5 kv 150,000 kva breaker at operating voltages in excess of rating.

Fig. 10 — Metal-clad switchgear installation using air blast breakers. Tests show that breakers like this offer exceptional integrated duty capacity with low maintenance requirements, even at high currents.

MAKING SHIPS GO

An outstanding feature of diesel-electric propulsion which cannot be disputed is smoothness of control. And these are the reasons why d-c makes such fine control so simple.

Henry Oman and Wm. H. Treptow

ELECTRICAL DEPARTMENT • ALLIS-CHALMERS MANUFACTURING COMPANY

● Most motors and generators built today go on shipboard. Every vessel requires dozens of motors for driving winches, pumps, fans, anchor windlasses, etc. These motors and the auxiliary generators that supply them power are relatively small, but there are also giant direct-current motors and generators being built for diesel electric propulsion.

Until recent years, steam engines and turbines were employed almost exclusively as prime movers for electric generators supplying propulsion and ship's service power. However, since the development of diesel engines, the advantages of propelling ships electrically have greatly increased, especially where direct current is the intermediary between engines and propellers. This is primarily because a simple and efficient control is available.

Diesel-electric drives have their advantages when considered from an overall viewpoint for a given vessel. This is evident from the large orders electrical manufacturers have for propulsion motors and generators; and diesel-electric drives are now being selected purely for their advantages, even when other drives are available.

Generators and motors

Diesel driven d-c generators and d-c propulsion motors for shipboard application are similar to commercial motors and generators, except for slight modifications. These generators and motors are of the shunt wound type, separately excited from either a pilot exciter or the ship's service bus. The armatures of the machines are connected in series in alternate sequence to form the propulsion circuit. The number of machines for a given shaft horsepower depends upon the operating efficiency of the vessel and flexibility of control desired.

Sometimes it is possible to use a low speed motor direct connected to the propeller shaft to eliminate reduction gears. This is an important factor when gears are not readily available. Usually, though, weight can be saved by using high speed electric motors that drive the propeller shaft through reduction gears. Motors with a maximum speed of 400 rpm are usually coupled direct, while motors with a speed rating above 400 rpm are geared to the propeller shaft.

The only special electrical feature of marine generators is a starting field on some units. This is a field which is connected in series with the armature across a storage battery for starting the diesel engine. In such cases it is more economical to put an extra field winding in the generator than to build a starting motor, or design the diesel engine to operate from starting air.

Propulsion motors are electrically similar to d-c motors used for land application. No special horsepower-speed rating is usually necessary because the motor is designed to drive the ship at its maximum horsepower. The horsepower requirements of a vessel vary with the cube of the speed, so if the vessel is operating at less than rated speed, the motor will be more than capable of handling the power requirements.

Mechanically, d-c marine propulsion motors and generators are lighter than land machines. The yoke is welded steel, and steel construction is used wherever possible to eliminate excess weight. All fittings are of such composition or so protected that corrosion will not occur in salt atmospheres. All marine machines are drip-proof in construction because there is usually considerable condensation in engine rooms.

Control requirements

Fine control is the one outstanding advantage of interposing electric motors and generators between diesel engines and the propeller of a vessel. The control equipment must be designed to comply with space and weight limitations and yet provide smooth and flexible performance during maneuvering of the vessel. Furthermore, it must be constructed for durability and service. To insure that requirements are met it is necessary for the control to withstand strict tests. In addition, proper protective devices must be included.

What does the control do?

In designing control for d-c marine propulsion, there are two questions which can be asked:

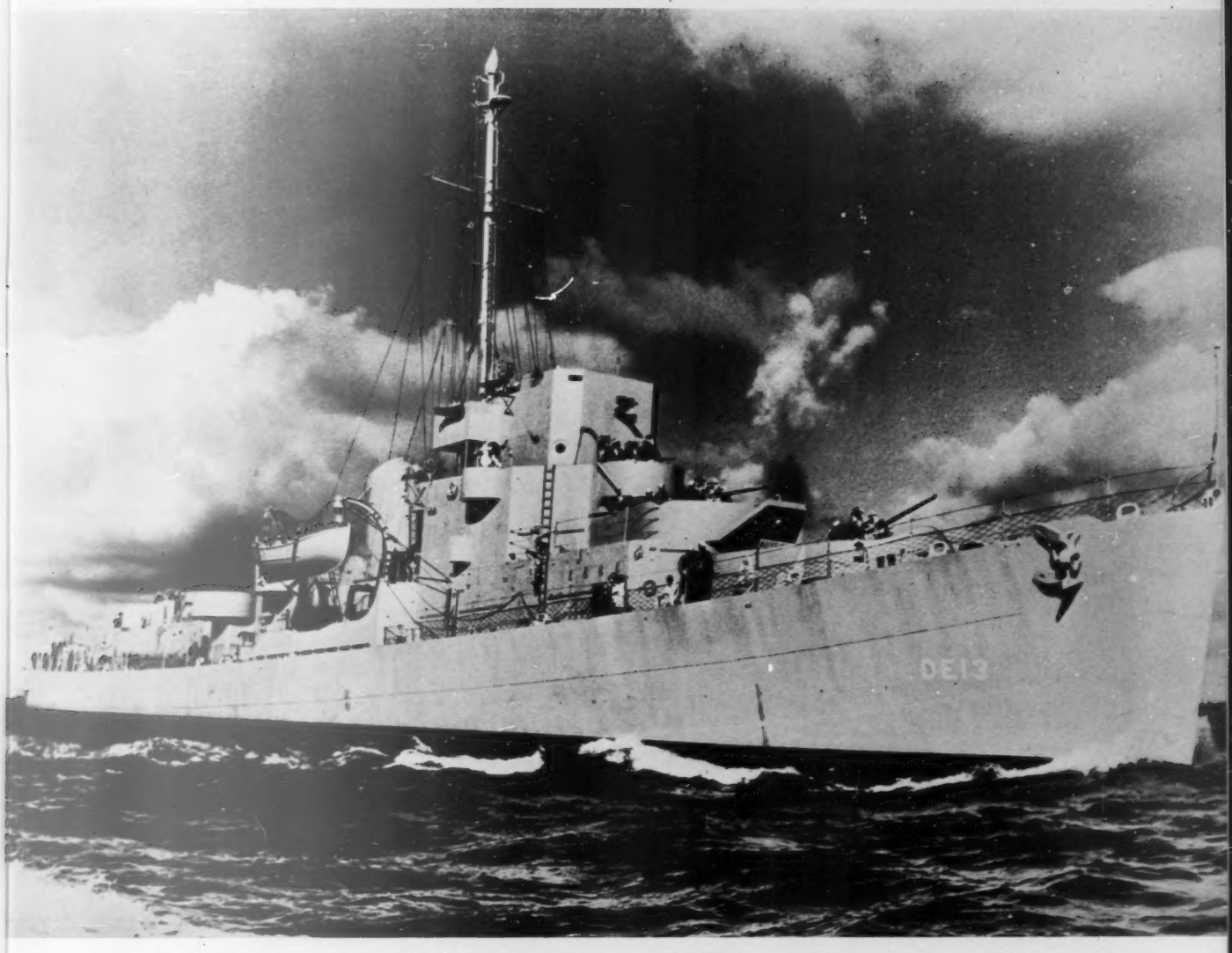


Fig. 1 — Diesel-electric driven escort vessels like this have helped to sweep enemy submarines from the seas. OFFICIAL U. S. NAVY PHOTO

1. What do we want the vessel to do?
2. What is the operator likely to do?

What the boat is likely to do is very simple. A vessel floats in water and goes either forward or backward at various speeds. Thus, the propulsion motor must go up to rated speed and rated horsepower; or it may have to go from full speed forward to full speed astern in the shortest possible time. It may also have to run at reduced speeds.

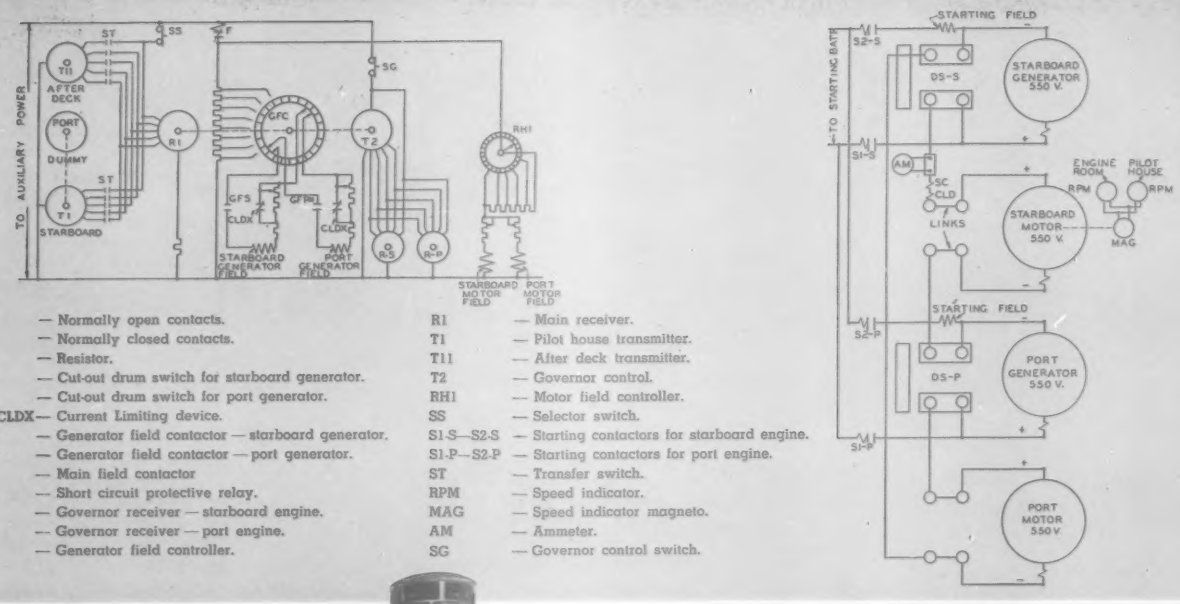
The operation of propulsion control must necessarily be simple. It is far more economical and efficient to design a propulsion control which can be operated by ordinary marine engineers without special training, than to design a cheaper control that would require highly skilled operators.

As a result, it is necessary that the control for operation full speed astern or full speed forward or any intermediate position be from a single lever. This may be located in the engine room or pilot house or a combination of the engine room, pilot house, and possibly after-deck. Furthermore, the control must be such that if the engineer becomes excited and moves the operating lever too fast, damage will not result to the machinery.

Diesel-electric propulsion must compete with other forms of propulsion in price. For this reason as well as space limitations, the control must have those items which are necessary for efficient propulsion, and nothing more.

How d-c propulsion control works

There is a surprisingly simple way of having electrical equipment perform these functions. In the first place,



	— Normally open contacts.	R1	— Main receiver.
	— Normally closed contacts.	T1	— Pilot house transmitter.
	— Resistor.	T11	— After deck transmitter.
DS—S	— Cut-out drum switch for starboard generator.	T2	— Governor control.
DS—P	— Cut-out drum switch for port generator.	RH1	— Motor field controller.
CLD—CLDX	— Current Limiting device.	SS	— Selector switch.
GF—S	— Generator field contactor — starboard generator.	S1-S—S2-S	— Starting contactors for starboard engine.
GF—P	— Generator field contactor — port generator.	S1-P—S2-P	— Starting contactors for port engine.
F	— Main field contactor	ST	— Transfer switch.
SC	— Short circuit protective relay.	RPM	— Speed indicator.
R—S	— Governor receiver — starboard engine.	MAG	— Speed indicator magneto.
R—P	— Governor receiver — port engine.	AM	— Ammeter.
GFC	— Generator field controller.	SG	— Governor control switch.

Fig. 2 — Basic design of a d-c propulsion control for a vessel having two engines, two generators, and two motors.

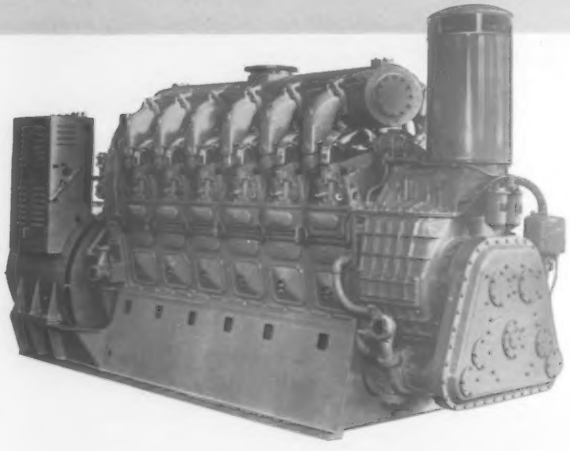


Fig. 3 — Diesel engine with coupled, 605 kw propulsion generator. Cabinet contains switches for by-passing unit when it is not running.

in a d-c system having more than one motor and one generator, the units are connected in series. This eliminates paralleling troubles and also reduces the maximum current that must be carried. Furthermore, the units are usually arranged with one motor connected to a generator, followed by a second motor which is in turn followed by a second generator. This results in the maximum voltage above ground being only the terminal voltage of the generator. The propulsion loop is kept closed for all normal operation, so consequently there are no arcing contacts.

The characteristics of a diesel engine are usually such that there is a minimum speed at which it can run satisfactorily. There is also a rated speed at which it will develop full power at the greatest efficiency. As a result, the basic function of d-c propulsion control resolves itself into a very simple operation.

In the modern control, to start the vessel, the diesel engines are started and set running at idling speed. The speed controller is designed to first increase generator field excitation by means of a potentiometer type field rheostat, until full field excitation is obtained. Next, the speed of the diesel engines is increased from idling to the desired operating speed. This is accomplished by a torque motor positioning system acting upon the diesel engine governor, which in turn controls the fuel supply of the diesel engine.

During these operations the control functions so that excess current will not flow in the circuit. The vessel may be maneuvered in the "ahead" or "astern" direction as desired by reversing the generator shunt field, thus reversing the armature polarity, which in turn changes the rotation of the propulsion motors, hence the ship's propeller. This is generally accomplished by means of a potentiometer type rheostat. The potentiometer rheostat makes it possible to adjust the generator field from zero to full; or full current of "ahead" polarity to full field current of "astern" polarity, without breaking the field circuit.

D-C position transmitter

The d-c position transmitter and receiver actuating the engine governor is fundamentally a potentiometer circuit at the control point and a motor which follows a potentiometer at the operating point. In this case, the motor is located at the engine governor. The system used is both amplifying and non-reversing; that is, torques which may accidentally occur at the engine's governor are not transmitted back to the operating point. The "d-c selsyn transmitter," as it is sometimes called, and the generator field rheostat can both be mounted on the same shaft; and the transmitter can have blank contacts in the operating range of the rheostat, and the rheostat can have blank contacts in the operating range of the transmitter.

On large vessels where two or more diesel driven generators are grouped to supply power to an equal number of propulsion motors, the generator shunt fields are connected in parallel and controlled simultaneously from a rheostat. The engine governor torque motors are also connected in parallel and controlled from their transmitter. The potentiometer type rheostat and the engine governor transmitter are mechanically coupled and operated as a unit.

These are the fundamental features of the propulsion control of a d-c diesel-electric drive.

Additions and refinements

The fundamental control just described would be operated from the engine room. It may be desirable to operate the control from the pilot house and also possibly from the after-deck. This is especially true for tugs where ease of manipulation of both propeller and rudder may be necessary for maneuvering the tug in tight places. Furthermore, the tug may be backing into a narrow space and it may be desirable to operate the control from the after-deck, where a clear view of the obstacles is available.

This remote control can be achieved again with a simple d-c positioning system. The receiver is connected to the same shaft as the engine room operating handle. At the pilot house, the transmitter is mounted in a control pedestal, and the receiver follows the movement of the control handle in the pilot house. There is no over-travel or oscillation, and hence no dampers, clutches, or brakes are required.

On some vessels, three or more control stands are required for convenient maneuvering of the vessel. When two or more control stations are desired on a vessel, proper switching arrangements must be provided, so that only one of the stations can be operated at a time.

It is desirable to keep the load balanced between engines. For this, a vernier adjustment in the governor transmitter is available, providing very fine engine speed control over a limited range.

The d-c drive also has the advantage of permitting torque adjustment for load variations at a given speed setting, for example, in tugboat service. This is accomplished by the motor field rheostat which controls the motor field strength over a limited range.

Generator field current is usually taken off the auxiliary bus in small drives. Where there are many large propulsion generators, it is usually more economical and efficient to provide exciters for the generators, in which case one exciter may serve a group of generators. The exciter armature is left connected to the generator field in normal operation and maneuvering. Reversing and changing speed are accomplished by a potentiometer arrangement, as described, on the exciter field. Exciters are usually driven by a motor connected to the auxiliary bus.

What to protect against

Here we find the answer to the second question—what will the operator most likely do? For design purposes, it can be assumed that the operator at some time or other will perform an operation with the control which will be likely to cause damage, unless the control prevents it inherently. It is against this, and also against accidental short circuits, engine failures, and electrical machinery failures that protection must be provided.

One thing that can happen in a propulsion control of this type is to lose the excitation from one of the motors. This will cause the motor to lose its torque and also put excessive voltage on the remaining motor. The loss of excitation will probably cause heavy currents to flow for a short time, and may, in addition, result in a flashover of any or all of the machines.

There are no circuit breakers in the propulsion loop series circuit. However, there is a field contactor which will open generator and motor field circuits simultaneously. An overload protection device actuated by a shunt in the series loop will open this field contactor when current exceeds something like 300 percent of normal. This provides protection against short circuits and failures in general.

There is also a likelihood that the operator will get excited and move his control lever a little too fast, and the inertia of the rotating machinery will not allow the motor speed to keep up with the movement of the control lever. This tends to increase the propulsion loop current. For that reason, a current limiting device is usually connected in the generator field circuit to automatically insert resistance in the generator field, if the current exceeds something like

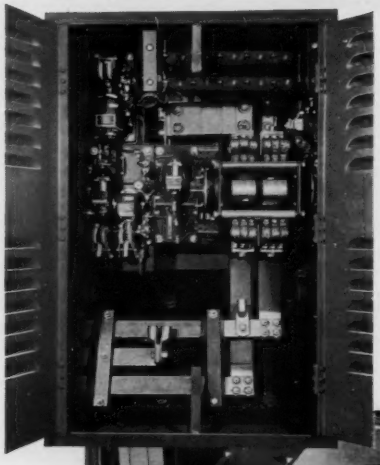
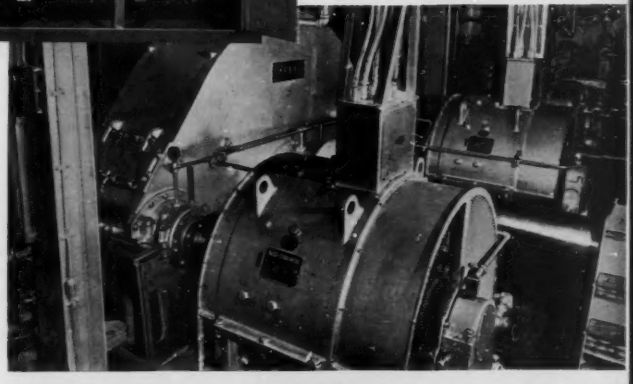


Fig. 4 (at left) — Interior of cutout switch cabinet in Fig. 3. Drum switch at right is for by-passing generator. Relays are for overload, reverse power, and field. Buses on bottom are generator terminals.

Fig. 5 (below) — Two propulsion motors coupled to the pinions of a large reduction gear. Two more motors are behind the gear. Propeller shaft in the middle carries 3,000 shp.



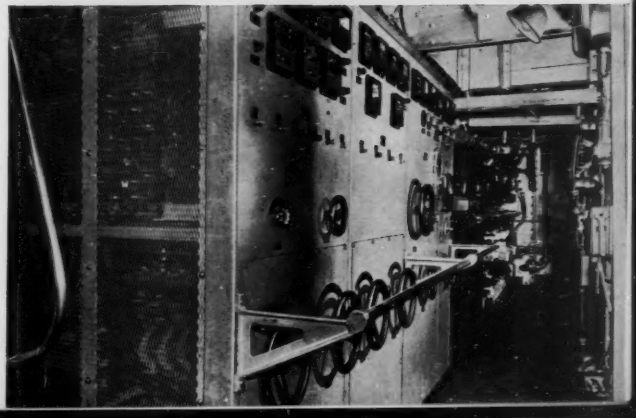


Fig. 6 (at right) — Engine room control for four-motor, four-generator 3,000 shp propulsion system. Handwheels on bottom are generator by-pass switches. The large handwheel in the middle is the main controller, the smaller handwheel the motor controller.

125 percent of normal value. The same relay also lights an indicating lamp to warn the engineers. If the current limiting indicating lamp lights in normal operation, then it may be necessary to adjust the motor field controller to slow down the motors.

Low speed efficiency

Cut-out and by-pass switches are usually provided for each motor and generator, and disconnects are in series with the machines. This makes it possible to run the boat with some propulsion motors or generators out of service. If it is necessary to run the vessel at reduced speed, it may be more economical to shut down several of the diesel engines and run the remaining engines at rated horsepower. Connections are usually provided to permit operation of all propulsion motors from one or more of the propulsion generators.

Some vessels are equipped with d-c propulsion motors rated in thousands of horsepower each. With such machines, the inertia of rotating equipment may be quite appreciable, and a form of current-limit acceleration and deceleration can be used in the control. In such a case, the current limiting relays and their field resistances would be replaced by current regulators operating in the field circuits of the generator exciters. This regulator is actuated from a shunt in the propulsion loop and it tends to maintain only maximum current during acceleration and deceleration.

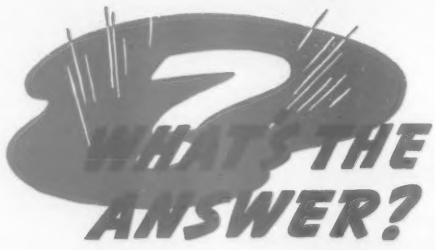
In a propulsion system having, say, four propulsion generators, considerable difficulty would be encountered if one of the engines failed. The result would be that the generator would motorize and drive the engine in reverse rotation. To prevent this, a reverse power relay may be provided. This consists simply of a relay with a beam balanced between the field current and armature voltage of the generator. In normal reversing, both field current and armature voltage reverse and the relay remains balanced. However, when the generator motorizes, the field current will continue to flow in the same direction, but the generator polarity will reverse. This actuates the relay, which in turn throws out all field contactors.

Instruments and indicators

In small tugboats, the number of instruments is usually kept to a minimum. An ammeter is always provided for reading propulsion loop current, and a voltmeter with a switch for reading the voltages of the various generators and motors can be supplied. An engine speed indicator may be mounted on the engine room control panel, and usually there is also a propeller speed indicator which runs off of a magneto on the reduction gear shaft.

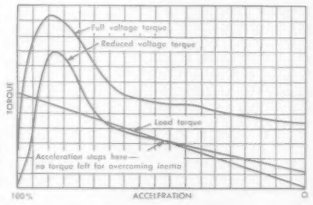
Numerous indicating lamps are supplied on propulsion control panels to show when trouble occurs. The field contactor and other operating relays are often equipped with interlocks which prevent operation of the propulsion control when all apparatus is not properly functioning.

Direct-current diesel-electric propulsion has demonstrated that it has unusual advantages, particularly in efficiency of control, and it may develop that when normal times return, diesel-electric drives will have something to offer which cannot be duplicated.



Question— I have a fan driven by a 200 hp induction motor. The motor has enough horsepower for the fan, but it will not come up to full speed when started across the line. What can I do? — W. E. P.

Answer— This is a problem often met with high-inertia loads. During acceleration the motor has to supply load torque, and whatever additional torque it has is used in overcoming rotational inertia. (See diagram.)



During the starting period the motor is drawing several times full-load current, so the line drop may be appreciable; and furthermore, the power system may not have enough capacity to maintain full voltage. As a result, the motor may be producing less than normal starting torque during a period when torque is most needed.

The solution is to increase the amount of available torque for accelerating the inertia. Since the motor torque is fixed by line voltage conditions, the increase of torque for accelerating purposes will have to be obtained by reducing the fan load. This can probably be done by shutting off the discharge with a vane or valve.

Question— What is the difference between a continuously excited and an intermittently ignited mercury arc power rectifier? — J. A. W.

Answer— In the intermittently ignited rectifier an arc is started in each individual rectifier tank once every cycle by means of an auxiliary electrode called an igniter. This electrode, made of a high resistance material, is partially immersed in the cathode mercury pool. High current impulses are passed through it into the mercury for short periods, in synchronism with the a-c supply voltage on the main anode. These current impulses start the emission of electrons from the cathode at the instant when the main arc is to be established. They are generated by a non-linear circuit which gives them the desired steep wave front.

In the continuously excited rectifier, called the excitron, a small pilot arc is established only once, when the rectifier is put on the line, and is maintained throughout the operating period. This arc is established by projecting a small jet of mercury, by means of a solenoid operated plunger, against a graphite auxiliary anode. The pilot arc is started when the mercury falls back into the cathode pool and breaks the circuit. This pilot arc is fed from a small source of direct current, such as a selenium rectifier.

"What's the Answer?" is conducted for the benefit of readers of ELECTRICAL REVIEW who have questions on central station, industrial or power plant equipment. Send all questions to the Editors of ELECTRICAL REVIEW.

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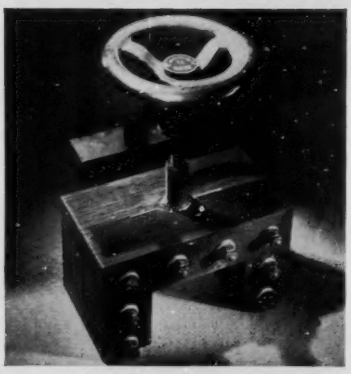
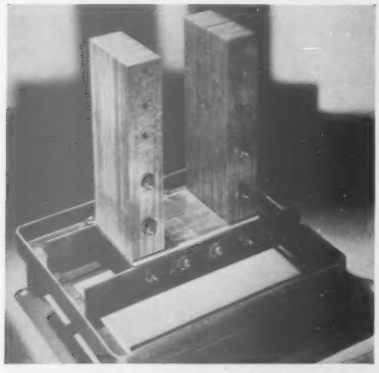
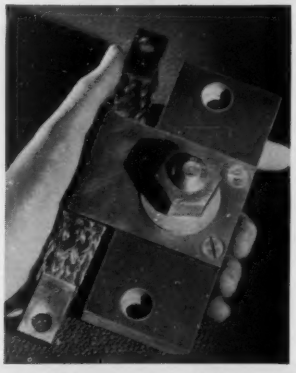


3 One inch movement of upper core — only 7 easy turns of wheel — covers entire welding range! Result: less wear, time saved!



4 Lower core is 1-piece, U-shaped, die-punched silicon steel. Eliminates air gaps, cuts idling loss. Note 1-piece welded frame, heavy angles.



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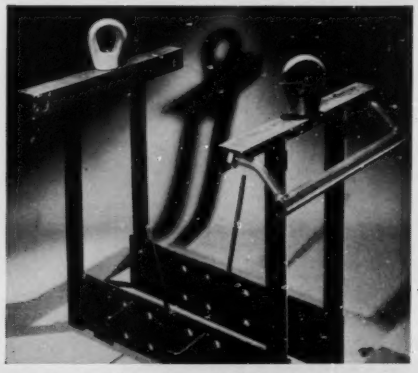
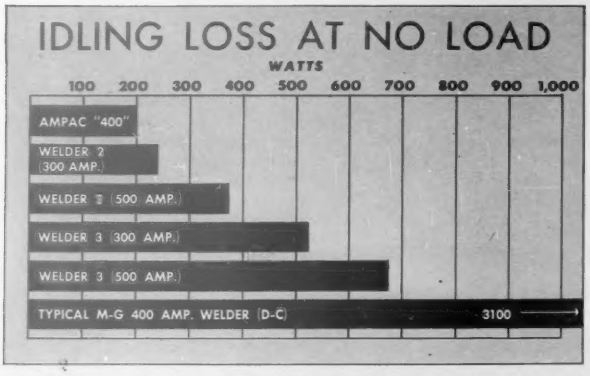


6 Sturdy lifting frame bolts to *core* for direct lifting of heavy mechanism. No load on case. Damage to case can *not* affect structure of electrical parts.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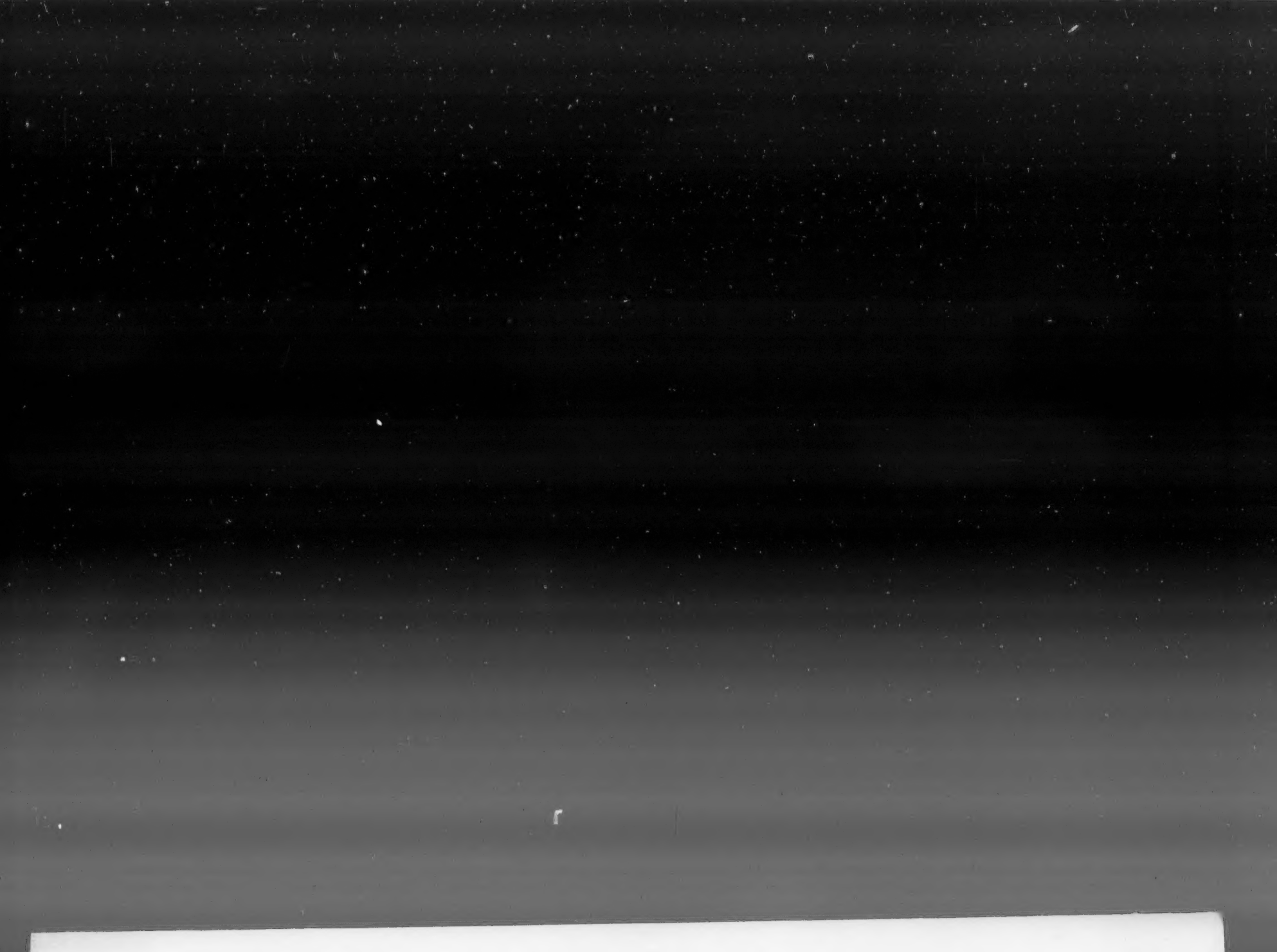
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